Atomic Energy Control Board
P.O. Box 1046
Ottawa, Canada
K1P 5S9

Commission de contrôle de l'énergie atomique
C.P. 1046
Ottawa, Canada
K1P 5S9

INFO-0277

COST-EFFECTIVENESS OF REDUCTION OF OFF-SITE DOSE

by

Atlantic Nuclear Services Ltd.

A research report prepared for the
Atomic Energy Control Board
Ottawa, Canada

March 1988

Canada

Research report

COST-EFFECTIVENESS OF REDUCTION OF OFF-SITE DOSE

A research report prepared by Atlantic Nuclear Services Ltd. under contract to the Atomic Energy Control Board.

ABSTRACT

Since the early 1970's, nuclear power plants have been designed and operated with a target of not releasing more than one percent of the licensed limits (derived emission limits) in liquid and gaseous effluents. The AECB initiated this study of the cost-effectiveness of the reduction of off-site doses as part of a review to determine if further measures to reduce off-site doses might be reasonably achievable.

Atlantic Nuclear has estimated the cost of existing technology options that can be applied for a further reduction of radioactive effluents from future CANDU nuclear power plants. Detritiation, filtration, ion exchange and evaporation are included in the assessment. The costs are presented in 1987 dollars, and include capital and operating costs for a reference 50 year plant life. Darlington NGS and Point Lepreau NGS are the reference nuclear power plant types and locations.

The effect resulting from the hypothetical application of each technology has been calculated as the resulting reduction in world collective radiation dose detriment. The CSA N288.1 procedure was used for local pathway analysis and the global dispersion model developed by the NEA (OECD) group of experts was used for dose calculations.

The reduction in the 'collective effective dose equivalent commitment' was assumed to exist for 10,000 years, the expected life-span of solid waste repositories. No attempt was made to model world population dynamics. The collective dose reductions were calculated for a nominal world population of 10 billion persons.

The estimated cost and effect of applying the technology options are summarized in a tabular form for input to further consideration of 'reasonably achievable off-site dose levels.

DISCLAIMER

The Atomic Energy Control Board is not responsible for the accuracy of the statements made or opinions expressed in this publication and neither the Board nor the author assumes liability with respect to any damage or loss incurred as a result of the use made of the information contained in this publication.

RÉSUMÉ

Depuis le début des années 1970, les installations nucléaires ont été conçues et dirigées de façon à ne pas libérer plus d'un pour cent des limites accordées (limites d'émissions dérivées) en effluents liquides et gazeux. La CCEA a entrepris cette analyse coût-efficacité de la réduction des doses hors-site dans le cadre d'une étude visant à déterminer si d'autres mesures en vue de réduire les doses hors-site pourraient être raisonnablement réalisées.

Atlantic Nuclear a estimé le coût des options technologiques actuelles pouvant être appliquées afin de réduire davantage les effluents radioactifs des installations nucléaires de type CANDU à l'avenir. La détritiation, la filtration, l'ionisation et l'évaporation sont incluses dans l'évaluation. Les coûts sont présentés en dollars de 1987 et comprennent les coûts de fonctionnement et en capital pour des installations de référence d'une durée de vie de 50 ans. La centrale Darlington et la centrale nucléaire de Point Lepreau sont les types et emplacements d'installations nucléaires utilisées à titre de référence.

L'effet résultant de l'application hypothétique de chaque technologie a été calculé comme s'il s'agissait de la réduction résultante des effets nocifs de la dose d'irradiation collective mondiale. La technique N288.1 de l'ACN a été utilisée pour une analyse des cheminements locaux et le mondèle de dispersion globale mis au point par le groupe d'experts de l'AEN (OCDE) a été utilisé pour calculer les doses.

On présumait que la réduction de l'équivalent de dose collective effective déterminée existerait pour 10 000 ans, soit la durée de vie prévue des dépôts de déchets solides. Personne n'a tenté de créer un modèle de la dynamique de la population mondiale. Les réductions de doses collectives ont été calculées selon une population mondiale de 10 milliards de personnes.

Le coût et l'effet prévus de l'application des options technologiques sont résumés dans un tableau qui pourra servir à considérer davantage les niveaux de dose hors-site pouvant être raisonnablement atteints.

ACKNOWLEDGEMENTS

The Project Manager for this study was James J. McGrath, B.Sc., P.Eng. He had developed its scope, content and emphasis before his tragic death in May, 1987. The project encompassed his professional expertise and personal commitments to the importance of the environmental impact of engineering projects, particularly electrical generating stations.

Atlantic Nuclear dedicates this report to the memory of Jim McGrath.

The project team that assisted Jim and completed the report included:

N. Arbeau - pathways analysis and dose calculations
R. Macphee - preparation of final report
J. Miskin - computer coding of dose calculations
C.K. Scott - project advisor and co-ordinator
E. Winters - cost assessments and waste management technology.

PREFACE

PURPOSE OF REPORT

This is an information report only. Its purpose is to provide data on technology options that can be used for further reduction of the radioactive emissions from future CANDU nuclear generating stations.

The data are the results of a study by ATLANTIC NUCLEAR for the Atomic Energy Control Board. Data provided are estimates of costs and of effectiveness in reducing local and world collective radiation dose detriments, for each technology considered.

The report is intended only to assist in evaluating the technology options. No judgments are made nor are any opinions expressed on the cost benefit of any technology.

REASONS FOR THE STUDY

The Atomic Energy Control Board (AECB) has accepted the principle recommended by the International Commission on Radiological Protection (ICRP) that radiation "exposures should be As Low As Reasonably Achievable (ALARA), economic and social factors being taken into account." This principle is applied to the control of both public and occupational radiation exposures. The application of the ALARA principle is an on-going process of review and, when justified, reduction in exposures. This study and report stem from the normal application of the ALARA review process to radioactive effluent control methods in nuclear generating stations in Canada.

Radioactive effluents from nuclear generating stations are required to be less than limits known as Derived Emission Limits (DELs) approved by the AECB. In keeping with the ALARA principle, in the early 1970's the AECB asked nuclear reactor operators to observe an operating target of one percent of the DEL limits for radioactive emissions. With few exceptions, these targets have been met by all Canadian nuclear power reactors in each year of operation. Emissions for most effluent groups are well below the 'one-percent-of-DEL' level.

Since the 'one-percent-of-DEL' operating targets were adopted, new technologies have been developed for the reduction of radioactive emissions from nuclear generating stations. Most newer technologies have not been adopted in existing plants, since the 'one-percent-of-DEL' operating targets have on the whole been met or bettered. However, treatment methods, such as filtration, are used to some extent at existing plants.

The alternative technologies have been reviewed by Atlantic Nuclear in this study, to determine the cost of applying them in new generating stations and to assess the potential reductions in radioactive emissions and dose which might so be accomplished.

It may well transpire that existing emission levels, regulatory limits and emission control methods are entirely adequate. This report will assist in determining whether or not that is so.

TABLE OF CONTENTS

	Page
ABSTRACT	i
ACKNOWLEDGMENTS	iii
PREFACE	iv
A. **EXECUTIVE SUMMARY**	
1. Overview	1
1.1 Summary of Results	4
1.1.1 Costs of Technologies and Emission Reduction	5
1.1.2. Dose Detriment Reductions	5
2. References	13
B. **REPORT OF FINDINGS**	
1. Introduction	14
1.1 Scope and Limits of Study	14
1.1.1 Effluent Groups and Pathways	15
1.1.2 Reference Sites	15
1.1.3 Dosimetric and Effluent Pathway Models	16
1.1.4 Emission Source Terms	16
1.1.5 Populations	19
1.1.6 Emission Reduction Technologies	19
1.2 Overall Methodology	20
2. Technologies and Treatment Methods - TRITIUM EFFLUENTS	21
2.1 Detritiation Technology	21
2.1.1 Rationale for Choice of Detritiation Technology	21
2.2 Detritiation-Method, Effectiveness and Costs	22
2.2.1 Costs of Detritiation Plants	23
2.2.1.1 Detritiation at Darlington NGS	23
2.2.1.2 Detritiation of Pt. Lepreau NGS Heavy Water	24
2.2.1.3 Accuracy of Estimates	25

3. Technologies and Treatment Methods - LIQUID EFFLUENTS 27

3.1 Radionuclide Content of Liquid Emissions 27

3.2 Character of Effluent Concentrations 30

3.3 Current Liquid Effluent Treatment Practice 33

3.4 General Notes on Liquid Effluent Treatment Technologies 34

3.4.1 Radionuclides Affected 34
3.4.2 Dose Detriment Reduction Considerations 34

3.5 Treatment Technologies Considered 35

3.5.1 Filtration 35
3.5.2 Ion Exchange 35
3.5.3 Reverse Osmosis 36
3.5.4 Evaporation 36

3.6 Estimation of Costs for Reference Sites 37

4. Technologies and Treatment Methods - GASEOUS EFFLUENTS 40

4.1 Assessment of Treatment Technologies 40

4.1.1 Iodine and Particulates 40
4.1.2 Noble Gases 41
4.1.3 Carbon-14 42

4.2 Summary of Treatment Technologies 43

5. Pathway Models and Detriment Calculations 45

5.1 Pathway and Dose Models 45

5.1.1 Model for Local Dose Calculations 45
5.1.2 Model for Regional Dose Calculations 46
5.1.3 Model for Global Dose Calculations 46

5.2 Source Terms for Reference Power Plants 48

5.3 Results of Detriment Calculations 50

5.3.1 Results for the Local Pathways 50
5.3.2 Results for the Global Pathways 51
5.3.3 Accuracy of Dose Calculations 51

5.4 Reduction in Detriment from Application of New Technologies 51

6. Conclusions 59

7. References 60

8. Bibliography 61

APPENDIX A Costs of Detritiation Plants and Shipment of Heavy Water

APPENDIX B Site Data for the Local Pathway Models

APPENDIX C Calculation of Global Dose Reductions

APPENDIX D Data from Local Dose Calculations

TABLES

		Page
Table 1.	SUMMARY OF RESULTS - Single Unit CANDU Station, 600 MW(e): Reference Plant = Point Lepreau II NGS	7
Table 2.	SUMMARY OF RESULTS - Multi-Unit CANDU Station, 4 x 850 MW(e): Reference Plant = Darlington NGS	9
Table 3.	SUMMARY OF RESULTS - Local and Global Collective Dose Savings - Point Lepreau II	11
Table 4.	SUMMARY OF RESULTS - Local and Global Collective Dose Savings - Darlington	12
Table 5.	Liquid Effluent Treatment Methods and Estimated Decontamination Factors	28
Table 6.	Typical Radionuclides Found in Radioactive Effluents from CANDU Nuclear Power Stations	29
Table 7.	Liquid Effluent Treatment Methods Summary for Point Lepreau II	31
Table 8.	Liquid Effluent Treatment Methods Summary for Darlington	32
Table 9.	Comparison of Available Evaporators for Radioactive Liquid Waste Treatment (from Reference 6)	38
Table 10.	Summary of Treatment Technologies for Gaseous Emissions	44
Table 11.	Source Terms for the Reference Sites	49
Table 12.	Reference Collective Dose at Point Lepreau II	52
Table 13.	Reference Collective Dose at Darlington	53
Table 14.	Reduction in Collective Dose from Application of Liquid Waste Technologies for Point Lepreau II	54
Table 15.	Reduction in Collective Dose from Application of Liquid Waste Technologies for Darlington	55
Table 16.	Reduction in Collective Dose from Tritium Technology at Point Lepreau II	56

Table 17.	Reduction in Collective Dose from Tritium Technology at Darlington	56
Table 18.	Reduction in Collective Dose from Air Emission - Point Lepreau II	57
Table 19.	Reduction in Collective Dose from Air Emission - Darlington	57
Table 20.	Global Collective Dose Commitment from Point Lepreau II	58
Table 21.	Global Collective Dose Commitment from Darlington	58
Table B.1	Distribution of Population Around Point Lepreau II NGS	B3
Table B.2	Point Lepreau II Wind Rose Weighting Factors	B4
Table B.3	Distribution of Population Around Darlington NGS	B5
Table B.4	Darlington Wind Rose Weighting Factors	B6
Table B.5	Atmospheric Dilution Factors for Point Lepreau II NGS	B8
Table B.6	Atmospheric Dilution Factors for Darlington NGS	B8
Table D.1	Definition of Transfer Parameters	D2
Table D.2	Transfer Parameters for the Darlington Site	D3
Table D.3	Transfer Parameters for the Point Lepreau Site	D15
Table D.4	Spatial Distribution of Individual and Collective Doses for the Darlington Site	D27
Table D.5	Spatial Distribution of Individual and Collective Doses for the Point Lepreau Site	D45
Table D.6	Program Listing for CLDOSL	D72

FIGURES

		Page
Figure 1	- Model for Effectiveness of the Reduction of Off-Site Doses from a Nuclear Power Plant	2
Figure 2	- Spatial-Temporal Dispersion Modelling	3
Figure 3	- Location of the Point Lepreau II NGS	17
Figure 4	- Location of the Darlington NGS	18
Figure 5	- Environmental Pathway Model	47
Figure A.1	- Estimated Capital Cost of Tritium Reduction Facilities	A2
Figure A.2	- Effect of Moderator Tritium Concentration on Capital Cost (600 MW(e) CANDU NGS)	A3

A. EXECUTIVE SUMMARY

1. Overview

Estimates for the reduction in local and world collective radiation dose detriment are presented, for a variety of technologies designed to reduce the radioactive emissions from two reference nuclear electric generating plants. Costs for the hypothetical application of each technology are also estimated. The technologies addressed are those available in 1987.

The Darlington station and a postulated Point Lepreau II station are the reference plants for this study. They are assumed to be operating as the model plants Bruce-A and Pt. Lepreau I to establish reference dose levels for current technologies. The new technologies are then evaluated to determine the further reduction in dose that can be achieved.

The effect of the application of the new technologies is illustrated in Figure 1. The box labelled 'Reduction Technology' represents the addition of a new technology or technique to current radwaste management practices. Only the liquid and gaseous streams are considered since the solid stream is not deliberately dispersed in the global environment.

The local and world radiation dose detriment can only be reduced by diverting radioactive material from either the liquid or the gaseous effluent streams to the solid waste stream. Current and planned management practices will withhold the solid radioactive waste from the biosphere until the activity is negligible or at least until the next ice age for the long-lived radionuclide component. The box labelled 'Solid Waste Dispersion' in Figure 1 is the dispersal of the solid waste in the biosphere after a delay corresponding to the expected life span of solid waste repositories (10,000 years).

The assessment of the reduction in radiation dose detriment given in this study does not include the dispersal of the solid radwaste. That is, the dose commitment is only calculated for the 10,000 year interval of hold up of the waste in a managed facility.

The individual and collective doses were calculated for the liquid and gaseous effluent streams before and after the application of the new technologies. In accordance with the ICRP recommendations [Ref. 1], the individual dose was calculated as the 'dose equivalent' expressed in Sieverts and the collective dose was calculated as the 'collective effective dose equivalent commitment' expressed in Person-Sieverts.

As shown in Figure 1, the dispersion of the radioactive effluents is considered on three scales spatially - local ($\sim$100 km), regional ($\sim$1000 km) and global ($\sim$ 10,000 km). The time dependence of the spatial dispersion is illustrated in Figure 2.

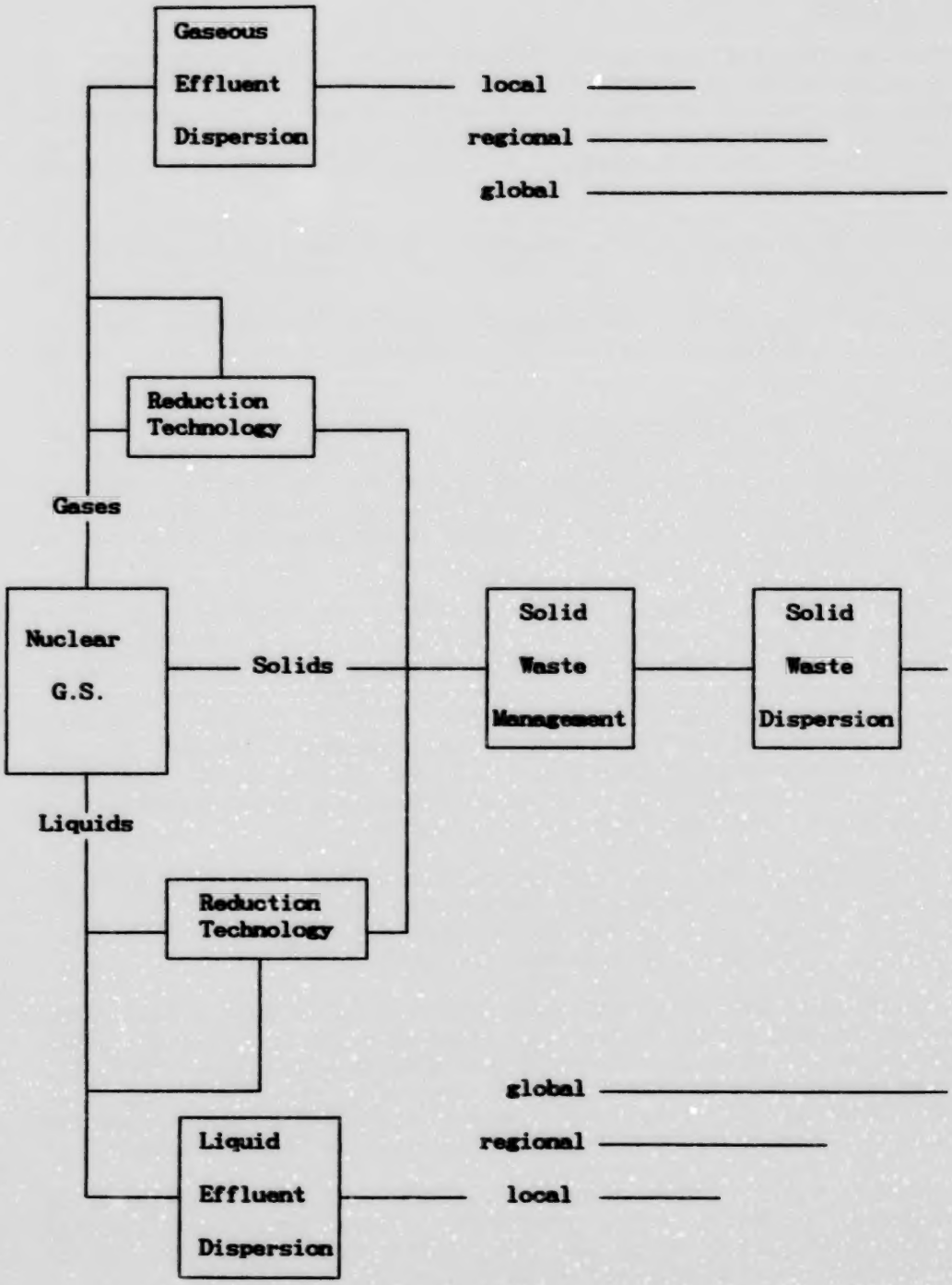


Figure 1. Model for Effectiveness of the Reduction of Off-Site Doses from a Nuclear Power Plant

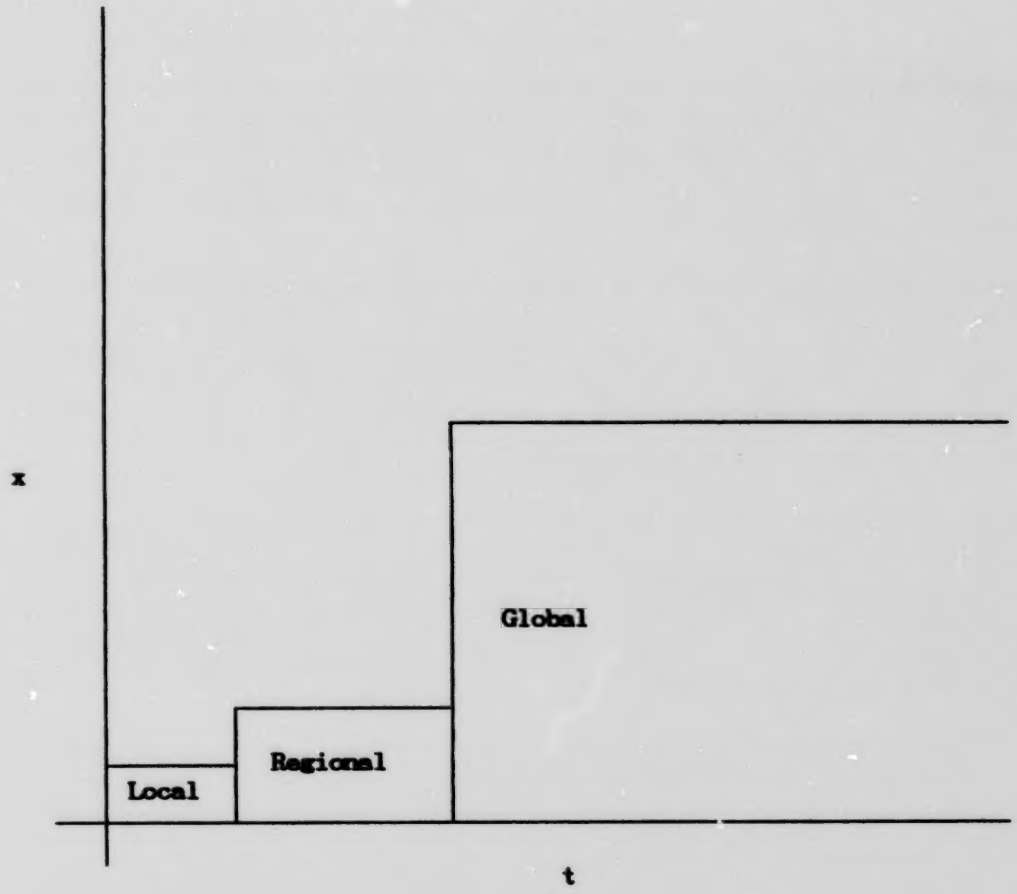


Figure 2. Spatial - Temporal Dispersion Modelling

Local dispersion affects the population living in the vicinity of the plant. Short-lived, as well as long-lived, radionuclides can be ingested by individuals from the airborne and waterborne pathways. Models for the local dispersion of radionuclides are site specific, accounting for population distribution, agriculture, fishing, geography, meteorology, etc.

Regional dispersion affects the population living in the vicinity of a large scale airborne or waterborne pathway. An example would be all cities and towns along the St. Lawrence River having drinking water contaminated by the liquid effluent from the Darlington NGS. The longer transit time decreases the importance of the short-lived radionuclides. Regional models are specific to the geographical location of each nuclear power plant.

Global dispersion affects the entire world population through global pathways. Only long-lived radionuclides (H-3, C-14, Kr-85, I-129) need to be considered because of the time scale and mechanisms necessary for global dispersion. The dispersion mechanisms are common to all nuclear power plant sites and account for atmospheric and water transport on the global scale. Details of the population distribution and activities are not important.

The project scope did not include the development of dispersion models. Existing models were applied to the Darlington and Point Lepreau sites. The CSA N288.1 procedure [Ref. 1] was used for calculating the dose locally. The global collective dose calculations were done with the models developed in the study by the NEA Group of Experts [Ref.3]. Models of dispersion by regional mechanisms do not exist for the Darlington or Point Lepreau sites. Thus, the calculations included the effect on the regional population in the global dose only.

Only effluents resulting from normal plant operation were considered in the dispersion models. Effluents arising from nuclear emergencies were outside the scope of the study.

1.1 Summary of Results

Atlantic Nuclear has estimated the cost of applying each technology to each of the reference stations, and estimated a resulting reduction in world collective radiation dose detriment resulting from the hypothetical application of each technology.

The calculated data is summarized in Tables 1 and 2, entitled 'SUMMARY OF RESULTS' at the end of Section A. Tables 3 and 4 give the separate contributions from local and global dispersion of radionuclides.

1.1.1 Costs of Technologies and Emission Reduction

The following technologies are addressed and the capital and operating costs are estimated for target emission reduction factors:

- detritiation
- filtration
- ion exchange
- evaporation
- charcoal delay beds
- CaOH scrubbers.

The costs are presented in 1987 dollars, and include capital and operating costs for a reference 50 year plant life. The reduction factors are presented as a percentage reduction in the activity of the effluent streams.

1.1.2 Dose Detriment Reductions

The reductions in collective doses are calculated for the entire world population for a period of 10,000 years, after which the next ice age is taken as beginning, for the purposes of this study. This includes a calculation of collective dose reduction for the local population for a period of 50 years.

The dynamics of the world's population over the 10,000 year interval were not modelled. A static population of 10 billion persons was used in all collective dose commitment calculations.

Only gaseous and liquid effluent paths are considered. The radionuclides considered are the following:

- Tritium
- Noble gases (Krypton-85 and Xenon-133)
- Iodines (Iodine-131 and Iodine-129)
- Carbon-14
- Liquid effluent contaminants other than tritium.
- Air particulates

Pathway and dosimetry models [Ref. 2,3] available in 1987 were used to estimate total world collective radiation dose detriment for each effluent group under reference conditions with existing emissions control technologies. Emission reduction factors for each technology were then used to estimate reductions in these detriments which could result from applying each of the technologies to the base case.

Collective dose detriments to operations staff at the stations were considered in compiling this report, but were not included in the world detriment totals since for each nuclide group except tritium they are insignificant compared with world collective radiation dose detriment totals. Operational dose detriments are received almost exclusively from external gamma radiation, from contaminated nuclear process

systems and from tritium uptakes. There are on-going programs to reduce the occupational exposure independent of new systems. This bias makes it difficult to assign an occupational dose detriment or benefit to the addition of a detritiation facility.

The question of occupational doses from the long-term management of the radionuclides withheld from the environment was beyond the scope of this project. It should be addressed if more refined calculations are considered to be necessary.

Caution is advised when using the data presented in this report, since:

(a) some of the technologies evaluated are not used widely as yet in nuclear generating stations
(b) there are several conservative assumptions in the dosimetric modelling process.

Costs cannot be based on experience of construction examples, except for detritiation plants. Neither are the costs estimated very accurately considering their magnitude, and given the limited scope of this study. The estimates given in this study are believed to be accurate within a factor of 2.

The dosimetric models used in this study are generally conservative (i.e. overestimate the dose), and therefore the estimated committed dose detriments and dose detriment savings may be larger than might actually be achieved if the technologies evaluated were to be employed. Overall, the predicted dose reductions are likely conservative by as much as a factor of 10. (This does not take account of the arbitrary treatment of future populations in calculating collective dose reductions.) For this reason, Tables 1 and 2 include the percentage reduction in emission of the radionuclide. The relative reduction will be more accurate than the absolute calculation of dose reduction.

Table 1. SUMMARY OF RESULTS

Single Unit CANDU Station, 600 MW(e) : Reference Plant = Point Lepreau II NGS

Case Number	Radionuclide Group/ Effluent Pathway	Effluent Reduction Technology and Treatment Method	50 year Cost 1987 dollars (x 1,000,000)	Effluent Reduction (%)	Total Collective Dose Reduction: (Person-Sv)
L 1.	Tritium, released via gaseous effluents.	Tritium removal plant built at Point Lepreau. Moderator water detritiated first.	192	66	5.0
L 2.	Tritium, released via liquid effluents.	As for L 1. above - same plant.	included in L 1. above.	66	4.1 E-3
L 3.	Noble Gases (Krypton-85, Xenon-133)	Charcoal bed delay tanks used to absorb and delay selected gas streams such as purge streams from the fuelling machine purification surge tank.	8	90	4.3 E-3
L 4.	Carbon-14	Absorber beds for removal of Carbon Dioxide from moderator cover gas.	0.25	90	2400
L 5.	Iodines and particulates via gaseous effluents	Additional filter trains.	0.15	90	1.6 E-6

Table 1. Summary of Results (continued)

Case Number	Radionuclide Group/ Effluent Pathway	Effluent Reduction Technology and Treatment Method	50 year Cost 1987 dollars (x 1,000,000)	Effluent Reduction (%)	Total Collective Dose Reduction: (Person-Sv)
L 6.	Liquid effluents other than tritium.				
	L 6.1	Filtration of 200 m^3/year: no effluent concentrations greater than 500 Bq/L.	0.10	60	8.7 E-3
	L 6.2	Filtration of 20,000 m^3/year and ion exchange processing of 200 m^3/year: no effluent concentrations greater than one (1) Bq/L.	10	94	1.4 E-2
	L 6.3	Filtration and ion exchange processing of 19,800 m^3/year, and evaporation of 200 m^3/year: no effluent concentrations greater than one (1) Bq/L.	80	99	1.4 E-2
	L 6.4	Evaporation of 20,000 m^3/year: no effluent concentrations greater than 0.5 Bq/L.	50	99	1.4 E-2

Table 2. SUMMARY OF RESULTS

Multi-Unit CANDU Station, 4 x 850 MW(e) : Reference Plant = Darlington NGS

Case Number	Radionuclide Group/ Effluent Pathway	Effluent Reduction Technology and Treatment Method	50 year Cost 1987 dollars (x 1,000,000)	Effluent Reduction (%)	Total Collective Dose Reduction: (Person-Sv)
D 1.	Tritium, released via gaseous effluents.	Tritium removal plant built at Darlington. Moderator water detritiated first.	240	66	62
D 2.	Tritium, released via liquid effluents.	As for L 1. above - same plant	included in L 1. above.	66	6.0
D 3.	Noble Gases (Krypton-85, Xenon-133)	Charcoal bed delay tanks used to absorb and delay selected gas streams such as purge streams from the fuelling machine purification surge tank.	18	90	12
D 4.	Carbon-14	Absorber beds for removal of Carbon Dioxide from moderator cover gas.	1.0	90	13,500
D 5.	Iodines and particulates via gaseous effluents	Additional filter trains.	0.50	90	<0.01

Table 2. Summary of Results (continued)

Case Number	Radionuclide Group/ Effluent Pathway	Effluent Reduction Technology and Treatment Method	50 year Cost 1987 dollars (x 1,000,000)	Effluent Reduction (%)	Total Collective Dose Reduction: (Person-Sv)
D 6.	Liquid effluents other than tritium.				
	D 6.1	Filtration of 300 m^3/year: no effluent concentrations greater than 12,000 Bq/L.	0.15	56	3.0
	D 6.2	Filtration of 30,000 m^3/year and ion exchange processing of 300 m^3/year: no effluent concentrations greater than 120 Bq/L.	16	95	6.4
	D 6.3	Filtration and ion exchange processing of 29,700 m^3/year, and evaporation of 300 m^3/year: no effluent concentrations greater than 12 Bq/L.	120	99	6.8
	D 6.4	Evaporation of 30,000 m^3/year: no effluent concentrations greater than 1.2 Bq/L.	75	99	6.8

Table 3. SUMMARY OF RESULTS

Local and Global Collective Dose Savings - Pt. Lepreau II (Person-Sv)

Radionuclide	Case	Local	Global
Tritium	L1, L2	0.46 E-2	5.0
C-14	L4	0.21 E-2	2400
Iodines	L5	0.16 E-5	0.76 E-11
Zinc-65 (liquid)	L6.1	0.86 E-2	-
	L6.2	0.14 E-1	-
	L6.3	0.14 E-1	-
	L6.4	0.14 E-1	-
Noble Gases	L3	0.11 E-2	0.32 E-2

Local Population = Static 135,348 for 50 years.
Global Population = Static 10 billion for 10,000 years.

Table 4. SUMMARY OF RESULTS

Local and Global Collective Dose Savings - Darlington (Person-Sv)

Radionuclide	Case	Local	Global
Tritium	D1, D2	10	58
C-14	D4	0.20 E-1	13,500
Iodines	D5	0.24 E-3	0.37 E-11
Co-60 (liquid)	D6.1	3.0	-
	D6.2	6.4	-
	D6.3	6.8	-
	D6.4	6.8	-
Noble Gases	D3	11.75	0.32

Local Population = Static 955,000 for 50 years.
Global Population = Static 10 billion for 10,000 years.

2. References

1. "Recommendations of the International Commission on Radiological Protection," ICRP Publication 26, January 17, 1977, Published for the ICRP by Pergammon Press, New York.

2. CSA Standard CAN3-N288.1, "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities," Draft #5 (unpublished).

3. "Radiological Significance and Management of Tritium, Carbon-14, Krypton-85, Iodine-129 Arising from the Nuclear Fuel Cycle," Report by an NEA Group of Experts, NEA/OECD, April 1980.

B. REPORT OF FINDINGS

1. INTRODUCTION

1.1 Scope and Limits of Study

The scope and limits of this study were set in agreement with the Atomic Energy Control Board.

The terms of reference for the study are as follows:

> "The study will examine alternatives for further reductions in off-site dose from effluents and direct radiation resulting from normal operation; including upset conditions or equipment failures that, based on experience at other plants, can be expected to occur during the lifetime of the plant, and which have an effect on off-site doses. The costing of alternatives will be in terms of capital and operating economic costs, including any consequential costs in other areas of the plant. Corresponding benefits will be expressed as estimated reduction of collective dose to persons off-site and to plant personnel. The long term effect of long-lived radionuclides discharged from the plant in trace quantities are also to be considered.
>
> The reduction in annual individual and collective dose should be presented as a function of time and distance from the plant. Simplifying assumptions rather than detailed demographic data may suffice for estimation of collective dose beyond the region of a given plant.
>
> In determining the reduction in dose obtainable from the various effluent control options, the contractor should not include individual doses which are so uncertain as to invalidate comparisons of the doses that would occur with and without the given option. Any computational cut-offs included for this reason should be identified and justified in the report. The contractor need estimate only that part of the collective dose that is prevented by any given control option.
>
> For this purpose it will be conservatively assumed that the plant operates for fifty years at an eighty percent capacity factor. All relevant pathways should be taken into account.
>
> To the maximum practical extent existing approaches and methods in the literature will be used for making dose calculations.

> The nuclear power plants to be selected for study are the four-unit Darlington Nuclear Generating Station (NGS) and the Lepreau II NGS. These two examples are chosen because they represent the latest designs, single and multi-unit designs (albeit with another operating unit at Lepreau), sea and fresh water locations, and low and high population densities in the vicinity."

Listed below are the important parameters of this study, and some of the limits of the study and limitations imposed on estimated data.

1.1.1 Effluent Groups and Pathways

Only liquid and gaseous effluents were considered; solid wastes were deemed to be effectively isolated until the next ice age, 10,000 years in the future. Therefore, doses and potential dose savings for solid waste handling and storage/disposal were not considered. No dose detriments were considered which might result from handling or disposal of any solid wastes (such as contaminated filters or ion exchange columns) produced by the effluent reduction technologies examined. Effluent groups considered were therefore:

Tritium - gaseous and liquid

Noble gases:

- Kr-85 - gaseous
- Xe-133 - gaseous

Iodine:

- I-129 - gaseous
- I-131 - gaseous and liquid

Carbon-14 - gaseous and liquid

Liquid effluent contaminants other than tritium, C-14, I-131

Air Particulates

1.1.2 Reference Sites

The reference sites are Darlington NGS and Point Lepreau II NGS. These were chosen in order to address single-unit and multi-unit plants, and encompass coastal and mid-continent sites, with differing local population figures. Each of the reference sites is deemed to employ current emissions control technologies to establish reference dose levels.

Point Lepreau II is taken to be a similar plant to the existing CANDU 600 Point Lepreau station. The location of the Point Lepreau site is shown in Figure 3.

The Darlington NGS is a 4 x 850 MW(e) unit station similar to Bruce A NGS. Figure 4 shows the Darlington site location.

1.1.3 Dosimetric and Effluent Pathway Models

A literature search was done to obtain information and models that could be applied in this study. The bibliography gives the relevant articles and reports that were identified.

The assessment of dose detriments [Ref. 1] in this study was confined to existing models since model development was not within the scope. The AECB was consulted on the final model selection. Also, they made available licensing reports from the utilities containing environmental and demographic data for the two sites.

For local collective radiation detriment, the compartment model adopted by the Canadian Standards Association was used in this study [Ref.2], with transfer parameters specific to the Darlington and Lepreau sites. This model includes the population within 50-100 km of the sites.

There are no regional models available for dispersion at distances of about 1000 km. These models are site specific and account for long range transport and non-uniform exposures to radioactivity because of geographical features. An example would be the transport of liquid effluents from Darlington through the St. Lawrence River system. Point Lepreau does not have a similar waterborne pathway. The regional population has been included in the total population in the global model.

The model for global dispersion of effluents is independent of the emitting site. The model developed by the NEA Group of Experts [Ref. 3] was used for the calculation of dose on the global scale.

The dose detriments to operating staff may make a significant contribution to the assessment of reductions in total detriment. However, there is not enough information available for a realistic estimate. In particular, models for the decommissioning of the facilites and the long-term waste management practices are not available

1.1.4 Emission Source Terms

The emission source terms are based on emission levels for the existing Bruce NGS A station (for the Darlington reference site) and the existing Point Lepreau station (for the Point Lepreau II reference site). Data for chronic releases from the Bruce and Lepreau stations was taken from Reference 4.

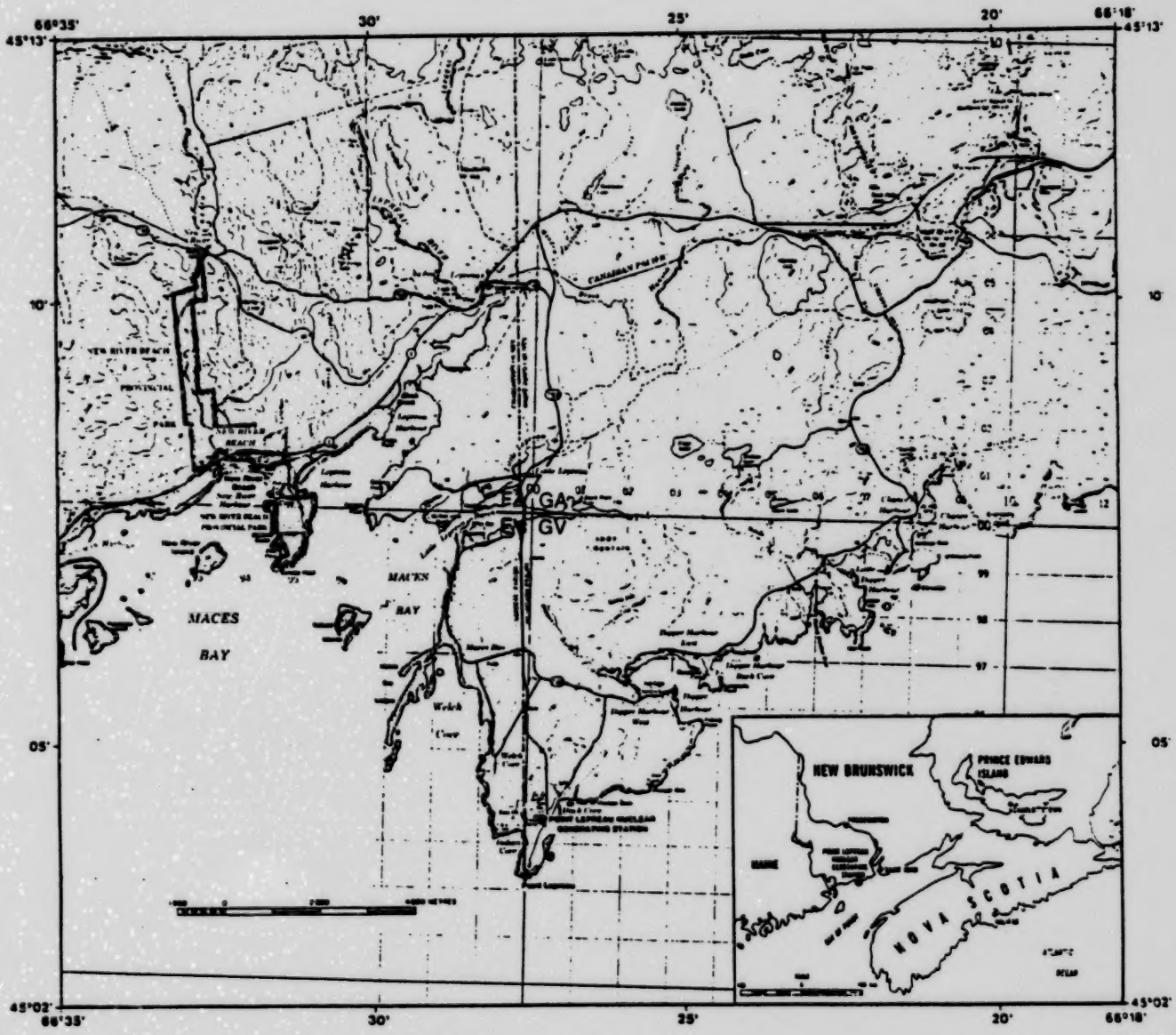
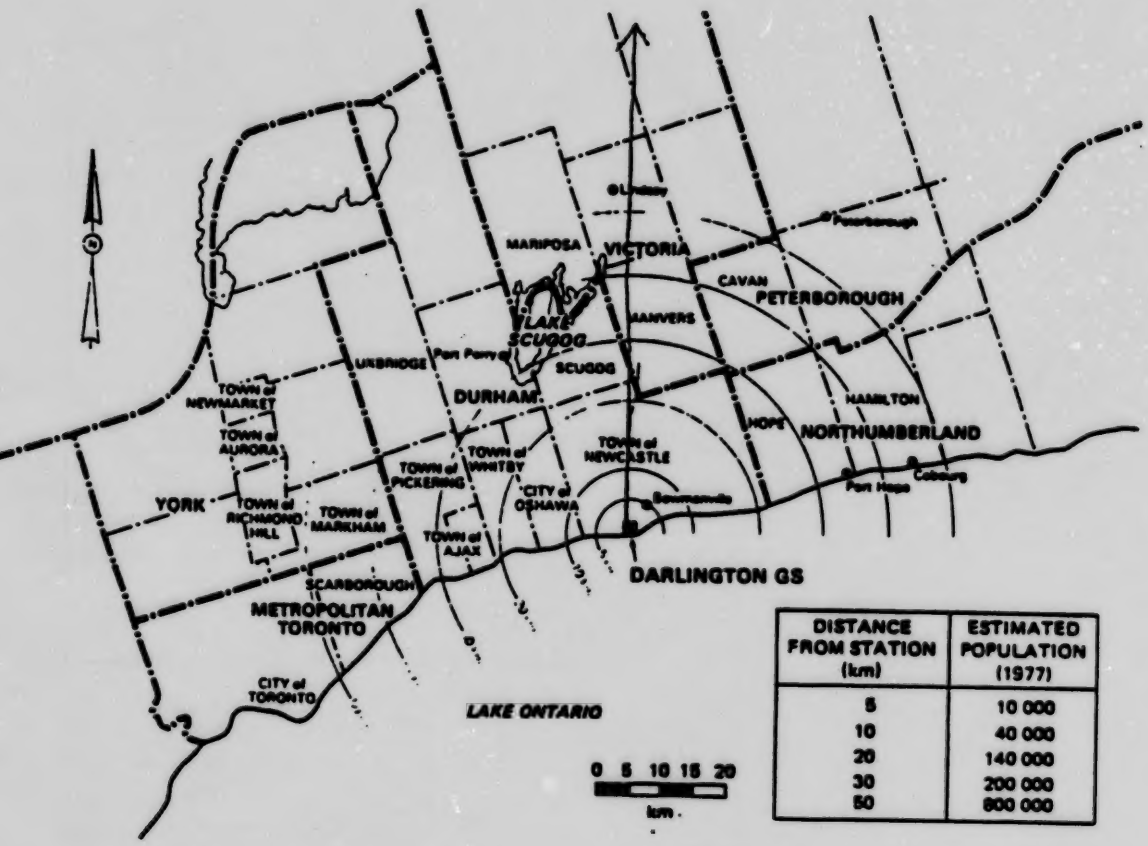


Figure 3. Location of the Point Lepreau II NGS



DISTANCE FROM STATION (km)	ESTIMATED POPULATION (1977)
5	10 000
10	40 000
20	140 000
30	200 000
50	800 000

Figure 4. Location of the Darlington NGS

1.1.5 Populations

Population data for the Darlington and Point Lepreau locations were used to calculate the doses in the local model. The distribution of population around the generating stations is given in Appendix B.

For global dispersion of long-lived radionuclides, the dose commitment is integrated over the next 10,000 years. No attempt was made to predict the world's population dynamics over this time. Instead, a static population figure of 10 billion was used. This approximation was used in the NEA study [Ref. 3].

Any model of the variation in the total population over 10,000 years would be speculative and would introduce large uncertainties into the dose predictions. The assumption of a plausible static total population sets a scale for the collective dose commitment that can be adjusted as required.

1.1.6 Emission Reduction Technologies

Emission reduction technologies have been studied by the Department of Environment [Ref. 5,6]. This work was the primary reference for selecting technologies to be evaluated in this study.

The costing of the reduction technologies included capital as well as operating costs. Costs estimates were compiled from discussions with experts in the nuclear industry and using recommended practices [Ref. 7,8,9].

1.2 Overall Methodology

For each radionuclide, there are four basic steps used in estimating cost-effectiveness of emissions controls:

1) Estimate rate of emission for each nuclide group for the reference site.

2) Using dosimetric and pathway models, calculate world total collective detriment [Ref. 1] resulting from these emissions. Local doses are calculated using a CSA 288.1 compartment model, programmed as a computer code [Ref. 2]. Global doses are calculated using tabulated data from the NEA/OECD report [Ref. 3].

3) Select a treatment method for the nuclide group, estimate its cost, and estimate its emission reduction factor. (For the case of liquid effluents, excluding tritium, several treatments were evaluated).

4) Estimate reductions in the world total collective detriment calculated in step 2 above by applying reduction factors reflecting emission reduction factors estimated in step 3 above.

Note: The compartmental method used assumes that there is a linear relationship between emissions and committed dose, i.e. halving emission rate of a nuclide will halve the resulting dose from that nuclide.

In Sections 2, 3 and 4 the technologies are reviewed and summarized. Estimates of the costs and emission reduction factors are presented. Tritium removal is treated as a special case in Section 2 while liquid and gaseous effluents are considered in Sections 3 and 4, respectively.

The calculations of individual and collective dose detriments are summarized in Section 5. Results from the dose calculations and cost estimates are then combined to give the final results presented in Tables 1 and 2.

2. Technologies and Treatment Methods - TRITIUM EFFLUENTS

The large inventory of heavy water used in the CANDU nuclear power plants leads to large inventories of tritium. As a result, the largest amount of radioactivity chronically released from a CANDU plant is tritium. It appears in both the liquid and gaseous effluent streams.

For reasons of economic and radiation safety, the management of heavy water inventories is a high priority with utilities. Further, facilities for removing tritium from the activated heavy water inventories are now being placed in-service. These facilities will reduce tritium releases from the plants.

The technology chosen in this study for reduction of tritium effluents is DETRITIATION, which is the process of reducing the tritium oxide content of the moderator and heat transport heavy water systems in a CANDU nuclear generating station.

2.1 Detritiation Technology

The methods chosen and evaluated for achieving detritiation are:

a) Point Lepreau - build a dedicated detritiation plant at the Point Lepreau site.

b) Darlington - as already decided by Ontario Hydro, use part of the total detritiation capacity of the Darlington TRF.

Over the assumed 50 year life of the reference plants, the most plausible assumptions of the effect of detritiation that can be made within the scope of this study are the following:

Assumption 1: Emissions to air and water will be based on current emission rates for the life of the reference plants.

Assumption 2: Detritiation will reduce gaseous and liquid tritium emissions by a factor of 3.

2.1.1 Rationale for Choice of Detritiation Technology

No practical method exists for removing tritium from either a gaseous or a liquid effluent stream, once it has entered the stream. Reduction of tritium in effluents can in 1987 only be done by reducing the amount of tritium entering the effluent stream. The three general methods for accomplishing this are:

a) Reducing the tritium concentration in process heavy water in the CANDU station (known as 'Detritiation').

b) Making heavy water process systems at the stations more leak-tight.

c) Performing operating, maintenance and heavy water handling procedures so that a minimum of tritium enters effluent streams.

The terms of this study do not consider changes to station operating procedures or changes to existing process systems as examinable effluent control technologies. Leak-tightness is an area of constant improvement in CANDU station design and operations, and therefore is part of the reference site status quo for the purposes of this study.

Station operating procedures and design changes have reduced tritium concentration in the operating environment of the station. The operating environment is the source of the tritium emissions to liquid and gaseous effluents. Considerable success has been achieved in this area, with the result that:

a) tritium effluent quantities have not increased in proportion with the normal rise in station tritium inventory over the life of existing stations [Ref. 4].

b) total personnel radiation dose detriments to Ontario Hydro operating staff have not increased despite the increase in the number of operating units, and an increase in total tritium inventory at the stations.

Without tritium removal technology, the inventory of tritium in the moderator system will increase throughout the life of the plant. For the reasons given above, the tritium emissions are not expected to grow proportionately. That is, the emissions are strongly biased by management practices.

Based on the industry experience, it is judged that detritiation technology will reduce tritium emissions by a factor of 3. This factor was assumed in the assessments reported in References 5 and 6.

2.2 Detritiation - Method, Effectiveness and Costs

Present detritiation processes consist of three steps:

a) A catalytic exchange process which transfers tritium atoms from a tritiated heavy water feed stream (where it exists as tritium oxide - HTO) into a deuterium gas stream extraction stream. Feed water is taken from the nuclear generating station systems or inventory, and is returned to the station after removal of a large portion of its tritium.

b) Cryogenic distillation of the deuterium gas stream to separate pure elemental tritium (HT) from the deuterium

stream, which is then recycled for further extraction of tritium from the tritiated heavy water feed stream.

c) Storage of the elemental tritium on metallic getter beds in a storage vault, where it decays into non-radioactive helium-3 with a half life of 12.3 years.

Two detritiation plants have been built in Canada and are currently in the commissioning stage. Commissioning of both plants is scheduled for completion in early 1988. The two plants are:

1) The Ontario Hydro Darlington Tritium Removal Facility (TRF) being built at the Darlington Nuclear Generating station

2) The Atomic Energy of Canada Limited Tritium Removal Plant (TRP) being built at Chalk River Nuclear Laboratories (CRNL).

In process design, the two plants are essentially the same except in the technique of transferring tritium atoms from the feed water stream to the deuterium gas stream. The CRNL TRP uses Liquid Phase Catalytic Exchange (LPCE), in which deuterium gas is passed through the tritiated feed water in the presence of a catalyst. The Darlington TRF uses Vapour Phase Catalytic Exchange (VPCE) in which deuterium gas and vaporized tritiated feed water are brought together in the presence of a hot catalyst.

The VPCE process has been demonstrated in France. It is more expensive to construct than the LPCE process, which has not yet been demonstrated on a pilot scale.

A key parameter of these plants is the detritiation factor, which sets the rate of conversion of tritium to the pure oxide form for storage. The detritiation factor is the ratio of tritium concentration in the feed water stream to the tritium concentration in the water returned to the station. For a fixed feed water throughput, the detritiation factor dictates the amount of tritium removed. For the Darlington TRF this will be 12. For the Chalk River TRP this will be 6.

2.2.1 Costs of Detritiation Plants

Details of the cost estimates for the detritiation plants are given in Appendix A and summarized in the following sections.

2.2.1.1 Detritiation at Darlington NGS

The Darlington TRF is designed to serve all of Ontario Hydro's 20 nuclear generating units (1987 total including four at Darlington) as a central detritiation facility. Detritiation of Darlington heavy water is expected to begin after the first Darlington unit has been operating for three years. When detritiation is applied to all four units at

Darlington, it will consume an estimated 20 per cent of the Darlington TRF processing capacity. The remaining 80 per cent capacity will be spent on detritiation of water from the total of 16 units at Pickering NGS and Bruce NGS. Therefore, the operating cost of detritiation for the Darlington NGS is set at 20 per cent of the cost of the Darlington TRF.

Parameters used to evaluate the effect of the Darlington TRF are:

Detritiation factor = 12

Target tritium concentration to be maintained in Darlington moderator heavy water = 0.37 TBq/Kg (10 Ci/Kg)

Feed rate of tritiated heavy water = 370 Kg/h

Reduction factor in H-3 emission rate = 3

Costs of detritiation for Darlington = $3.6 million per year.

The annual cost of detritiation for Darlington is a portion of capital and operating costs for the complete plant (See Appendix A).

2.2.1.2 Detritiation of Pt. Lepreau II NGS Heavy Water

There are three choices for detritiation of Point Lepreau II heavy water:

a) Build a dedicated detritiation plant at Point Lepreau to serve Point Lepreau II, or
b) Ship heavy water to Darlington for detritiation, or
c) Ship heavy water to CRNL for detritiation.

The costs for each option are similar, within the cost-estimation accuracy range of this study, and are in the range $3.5 million to $4 million per year.

Therefore, on the basis of operational convenience, the chosen option is a dedicated detritiation plant at Point Lepreau. It is reasonable to assume that the two present owners of detritiation plants will give first priority to their own needs, and that heavy water shipped from Point Lepreau would occasionally have to wait for detritiation. For a utility with one CANDU plant, and therefore limited stocks of heavy water, this might prove an unacceptable inconvenience when the dedicated-plant option, of similar cost, would avoid the possibility entirely, given an acceptable reliability factor for the plant. It is logical to assume that the Pt. Lepreau I station would use the detritiation plant as well, although no credit is given in this report for such a scenario.

Based on an examination of tritium removal plant technology and costs, parameters used for a Point Lepreau detritiation plant are:

Detritiation Factor = 12

Target tritium concentration to be maintained in Point Lepreau moderator heavy water = 0.37 TBq/kg (10 Ci/Kg)

Feed rate of tritiated heavy water = 37 Kg/h

Reduction factor for H-3 emissions = 3

Cost of Detritiation for Point Lepreau II = $3.6 million per year.

The annual cost represents capital amortization and operating costs for the complete plant. (See Appendix A).

2.2.1.3 Accuracy of Estimates

Tritium emission rates in effluents for a given reactor depend on many factors, including station operating conditions and the different concentrations of tritium in heat transport heavy water and in moderator heavy water. None of these factors is constant, nor are they directly related to one another in strict terms. This makes it difficult to accurately predict the effect of detritiation on instantaneous or annual tritium emission rates, in either gaseous or liquid effluent streams. Typically, for a CANDU power reactor more than ten years old, moderator tritium concentration is in the order of 20 or more times greater than heat transport tritium concentration; moderator tritium concentration might be in the range 40 -120 TBq/Kg, and heat transport tritium concentration might be in the range 2 - 6 TBq/Kg. Thus, if the emissions are not proportional to the moderator and heat transport system tritium concentrations, then the assumptions made in this study are conservative.

Fresh heavy water to make up for operational losses can be fed into the heat transport system; heavy water losses from the moderator system can be made up with lower tritium concentration feed from the heat transport system. As the moderator concentration is reduced by both these means, it should stabilize at 370 GBq/Kg for both reference plants. This concentration is considered to be an optimum figure, considering:

a) equilibrium moderator concentrations of tritium for a mature CANDU power reactor without detritiation could rise to the range of 2 to 4 TBq/Kg

b) moderator tritium concentrations in Point Lepreau I and all operating Ontario Hydro reactors considerably exceed 370 GBq/Kg in 1987

c) it permits construction of a detritiation plant which would be in the best unit cost range, and function efficiently at lower tritium concentrations. Were the target moderator tritium concentration to be chosen as, say, 37 GBq/Kg instead of 370 GBq/Kg, then the capital cost would increase by a factor of 3 to about $36 million for Pt. Lepreau II (Fig. A.2).

3. Technologies and Treatment Methods - LIQUID EFFLUENTS

The chief reference source for this section is from the work of the Department of Environment [Ref. 6], "Radioactive Liquid Wastes from Steam Electric Generating Stations" - Draft No. 3 (Discussion Paper Prepared for Working Group 5(2) "Radioactivity" Task Force on Steam Electric Power Generation). Information from this source is supported by references appearing in the text.

This section applies to metallic elements in liquid effluents, and to carbon-14 and iodines. Liquid effluent reduction technologies discussed here will not alter tritium levels in liquid effluents, since tritium is in the oxide (water) form, and hence highly mobile. Carbon-14 and iodines are assumed in this study to be removed from liquid effluents by any given technology with the same decontamination factor as applies to the metallic radionuclides. This assumption is based on information from Ontario Hydro and on the chief reference source for this section.

The technologies chosen were selected from a list of alternatives presented in Reference 6, which are listed in Table 5.

The technologies studied were chosen from this list based on cost effectiveness. If two technologies had the same decontamination factor but one cost substantially more, then the less expensive option was reviewed more rigorously.

3.1 Radionuclide Content of Liquid Emissions

The wide range of radionuclides in liquid effluents appear as dissolved material or as ions attached to suspended material. Like the radionuclides in gaseous effluents, they have two primary sources, fission products (generated within the uranium dioxide fuel) and activation products (created by neutron activation of dissolved and suspended material in reactor process systems).

Typical radionuclides actually found in liquid effluents are given in Table 6. This group was used in evaluating dose reductions (See Section 5).

For the purposes of this study, the radionuclides affected by liquid effluent treatment technologies are assumed to consist of what are known as the 'most restrictive' radionuclides. These are the radionuclides in the mix which deliver, per Becquerel emitted, the largest dose to the critical group in the public.

The 'most restrictive' radionuclide may be different for each reactor site, depending on surrounding population distribution and terrain, and the food consumption and living habits of the surrounding population. Further details may be found in Section 5 and Appendix B.

Table 5. Liquid Effluent Treatment Methods and Estimated Decontamination Factors

Treatment Method	Estimated Decontamination Factor
Filtration	10
Ion Exchange	100
Filtration in combination with Ion Exchange of a selected portion of station effluent liquids	1,000
Reverse Osmosis	100
Evaporation	10,000
Reverse Osmosis in combination with Evaporation of a selected portion of the effluent liquids	1,000
Evaporation after ion exchange of liquids	1,000,000

Table 6. Typical Radionuclides Found in Radioactive Effluents from CANDU Nuclear Power Stations

H-3	Sr-89
C-14	Sr-90
Fe-59	Zr-95
Co-60	I-129
Zn-65	I-131

For liquid effluents, the most restrictive radionuclides in this study are:

(a) Co-60 for Darlington

(b) Zn-65 for Point Lepreau II.

All released activity from liquid waste streams from the reference station is assumed to be this radionuclide.

Tables 7 and 8 summarize the reduced emission levels resulting from hypothetical application of selected emission reduction technologies, and the costs of application for each reference site.

3.2 Character of Effluent Concentrations

Waste liquids are collected from various areas and systems of the stations and collected in holding tanks. Depending on the source, the liquids vary widely in radionuclide mix and concentration. It is standard practice, as far as possible, to delay discharging effluents to station outfall streams so that their radionuclide content is reduced by radioactive decay.

The waste liquids are collected in different holding tanks depending on their origin in the station and therefore their likely volume and radionuclide concentration levels.

Liquid wastes can be categorized into three radioactivity levels:

Insignificant activity - in the range of 10 Bq/L or less
Low activity level - in the order of tens of Bq/L
Higher activity levels - in the order of kBq/L

This report assumes that for each reference site:

a) one third of the total annual effluent volume contains no significant activity;

b) one per cent of the remaining two thirds contains 50 percent of all activity discharged.

Table 7. Liquid Effluent Treatment Methods Summary for Point Lepreau II

Total Liquid emissions (excluding tritium) for Point Lepreau II, without treatment = 2.0 GBq/year

Treatment Method	Reduced Annual Emissions	Application parameters at Point Lepreau II	Annual Cost 1987 Dollars
Filtration	1.2 GBq	Filtration of 200 m^3/a: no release > 500 Bq/L.	$2,000
Filtration combined with Ion Exchange	0.11 GBq	Filtration of 20,000 m^3/a and Ion Exchange treatment of 200 m^3/a of that quantity. No release > 5 Bq/L.	$210,000
Evaporation	0.2 MBq	Evaporation of 20,000 m^3/a No release > 0.5 Bq/L.	$1 M
Filtration plus Ion Exchange plus Evaporation	1.1 MBq	Filtration and Ion Exchange treatment of 19,800 m^3/a plus Evaporation of 200 m^3/a. No release > 1 Bq/L.	$1.6 M

Table 8. Liquid Effluent Treatment Methods Summary for Darlington

Total Liquid emissions (excluding tritium) for Darlington, without treatment = 70 GBq/year

Treatment Method	Reduced Annual Emissions	Application parameters at Darlington	Annual Cost 1987 Dollars
Filtration	38 GBq	Filtration of 300 m^3/a: no release > 1,200 Bq/L.	$3,000
Filtration combined with Ion Exchange	3.5 GBq	Filtration of 30,000 m^3/a and Ion Exchange treatment of 300 m^3/a of that quantity. No release > 5 Bq/L.	$320,000
Evaporation	7 MBq	Evaporation of 30,000 m^3/a No release > 1.2 Bq/L.	$1.5 M
Filtration plus Ion Exchange plus Evaporation	38 MBq	Filtration and Ion Exchange treatment of 29,700 m^3/a plus Evaporation of 300 m^3/a. No release > 12 Bq/L.	$2.4 M

Using this basis, the following characterization of emissions was made:

(a) Point Lepreau Liquid Emissions

Total annual effluent volume discharged to station outfall =30,000 m^3/a.

Total activity discharged annually (all regarded as being Zn-65) = 2 GBq/a.

Average concentration of activity discharged = 67 Bq/L.

Makeup

Volume with no activity:	10,000 m^3/a
Volume containing 50 Bq/L:	19,800 m^3/a
Volume containing 5,000 Bq/L:	200 m^3/a
Total Volume	30,000 m^3/a

(b) Darlington Liquid Emissions

Total annual effluent volume discharged to station outfall =45,000 m^3/a.

Total activity discharged annually (all regarded as being Co-60) = 70 GBq/a.

Average concentration of activity discharged = 1.6 kBq/L.

Makeup

Volume with no activity:	15,000 m^3/a
Volume containing 1.2 kBq/L:	29,700 m^3/a
Volume containing 120 kBq/L:	300 m^3/a
Total Volume	45,000 m^3/a

3.3 Current Liquid Effluent Treatment Practice

As mentioned above, delay in holding tanks is the method in current use for reducing activity in liquid effluents. Several sites (Pickering, Bruce and Point Lepreau I) have filtration and/or ion exchange systems for decontaminating liquid effluents, but these are not being used to achieve emission limits substantially less than one percent of the Derived Emission Limits. Since liquid wastes collected in holding

tanks only very rarely exceed the maximum permitted discharge levels, and are normally less than one per cent of the Derived Emission Limits, there is at present no strong reason for increased operation of these filtration and ion exchange effluent control systems.

3.4 General Notes on Liquid Effluent Treatment Technologies

3.4.1 Radionuclides Affected

All radionuclides, except tritium, will be reduced to some extent by applying these technologies. Reference 6 notes (Section 3.3 - Wastewater Treatment):

> "The radionuclides are physically or chemically combined with non-radionuclides. 'Crud' is a combination of undissolved radioactive and non-radioactive solids, absorbed and adsorbed with each other. Chemically, a radioisotope acts the same as its non-radioactive isotope of the same atomic number (i.e. same number of protons and electrons). Consequently, if undissolved and dissolved solids are reduced in radioactive liquid streams, the radioactivity will be correspondingly reduced."

Section 3.5 adds further information where appropriate for specific treatment technologies.

3.4.2 Dose Detriment Reduction Considerations

a) Decontamination factors (DFs) given in this report (from Reference 6) are underestimates of attainable decontamination factors. Therefore, dose detriment reductions may in fact be greater than those we estimate using the recommended decontamination factors.

b) Radioactive solid wastes will be generated from reduction of radioactivity in liquid effluents. These may be in the form of contaminated filter elements, used ion exchange resins, or evaporator residues. Handling of these in the plant will cause some occupational radiation dose and disposal of these wastes could ultimately deliver a dose detriment to the public. When evaluating reductions in dose due to liquid effluent treatment methods, these additional detriments should be borne in mind. The terms of this study did not include estimation of these additional, counterbalancing detriments.

3.5 Treatment Technologies Considered

3.5.1 Filtration

Filtration was selected for application in this study, because of its widespread use in nuclear decontamination in closed circuit systems, and because costs and efficiencies are well documented.

Filtration is an old industrial technology, but is not being used extensively for treatment of radioactive liquid effluents from CANDU plants, for reasons mentioned above. Therefore, it is considered a 'new' technology for the purposes of this study.

The assumed decontamination factor is 10 (as recommended by Reference 6) for an industrial fine filter, although decontamination factors of up to 100 have been recorded for filtration of contaminated oil with Millipore filters. The DF of 10 would take into account change in filter efficiency over its useful life.

A large variety of filtration methods could be used. Filters with disposable cartridges would be most suitable for radioactive streams, to avoid the liquid and particulate wastes generated by backflushing reusable filter elements. Filtration will therefore generate a quantity of solid radioactive waste which must be dealt with.

The cost characteristics of filtration are a low capital cost and a high operating cost due to a large volume of spent filter cartridges requiring disposal as solid waste.

3.5.2 Ion Exchange

This technology was selected for application in this study, although not in isolation. Where ion exchange is used, the liquid stream is assumed to be filtered first to avoid fouling the ion exchange resins. Like filtration, ion exchange costs and efficiencies are well known for nuclear applications other than waste treatment.

The cost characteristics of ion exchange are low capital cost and a high operating cost due to a large volume of spent resin requiring disposal as solid waste.

Reported decontamination factors for ion exchange columns in nuclear applications range from 100 to 1,000 [Ref. 6]; this study assumes a DF of 100 for this process.

Ion exchange is a very well known technology, and is used in CANDU and other nuclear power stations to decontaminate circulating fluids in closed circuit systems, especially those whose liquids are exposed to neutron activation or to contamination. The moderator heavy water, for example, is continuously purified by filtration and ion exchange columns.

The process is most suitable for low conductivity liquids, although it will process small volumes satisfactorily with up to 2.5 g/L of dissolved solids. Since waste streams by their nature must be assumed to be dirty, this study assumes that ion exchange processing is only used following a filtration stage.

3.5.3 Reverse Osmosis

This technology was not selected for evaluation, because it is still under development for nuclear applications, although it has seen extensive use in water purification and waste treatment. It is mentioned because it has to some extent been evaluated by Chalk River Nuclear Laboratories to pilot scale. The decontamination factor is similar to IX and filtration but at a higher cost; thus, it was not seriously evaluated for a CANDU station.

Reverse osmosis technology is characterized by medium capital cost and medium operating cost.

In describing the process we cannot improve on the description in Reference 9 (Section 3.3.4):

> "Reverse osmosis is a technique where pressure applied to an aqueous solution forces water through a semi-permeable membrane. Since only a small fraction of the solutes and none of the suspended solids permeate through the membrane with the water, the retained liquid (the retenate) becomes increasingly concentrated while the permeate remains relatively very dilute."

3.5.4 Evaporation

This technology was selected for application in this study because it has been widely used in Japan and the United States for decontaminating liquid wastes from nuclear power stations. Many designs of evaporators exist. They are listed for comparison in Table 9 on page 38, in a list compiled by Chalk River Nuclear Laboratories [Ref. 6].

Reported decontamination factors range from 100 to one million. Following Reference 6, this study assumes a DF of 10,000.

Evaporation technology is characterized by high capital cost and medium operating cost, largely due to energy costs. It is more cost-effective when used alone rather than in combination with filtration and/or ion exchange.

Reference 6, Section 3.3.3, describes evaporation as:

> "... a unit operation in which the volatile and non-volatile components of a solution or slurry are separated by boiling away the volatile components. This process has been used extensively at nuclear facilities in the United States and Japan for both reducing waste volumes and the amount of radioactivity in the liquid effluents discharged. The process can be used on liquid waste streams of widely different compositions and concentrations, although it is generally less effective on very dilute solutions. The vapour from an evaporator is usually condensed and re-used, treated further or discharged. The concentrate or residue may be immobilized and stored."

In Canada, only Douglas Point Nuclear Generating Station has used an evaporator. As of late 1982 (date of the study, in Reference 9), at least 30 U.S. nuclear stations had purchased evaporators from one manufacturer alone.

Feed flow rates can range from 0.2 L/s to 2 L/s. Evaporators work best with Total Dissolved Solids (TDS) concentrations in the feed liquid of greater than one g/L, above which they give the best decontamination factors.

Note that evaporators will not remove tritium or ruthenium because of their volatility.

3.6 Estimation of Costs for Reference Sites

Tables 7 and 8 summarize costs for the different liquid effluent treatment approaches for each reference station.

The volumes of waste treated are based on the liquid effluent discharge model given in Section 3.2. Different technologies are combined for multiple treatments as follows:

1) Filtration of high activity waste.

2) Filtration of high and low activity waste followed by ion exchange treatment of the high activity waste.

3) Evaporation of all active waste.

4) Filtration and ion exchange treatment of the low activity waste and evaporation of the high activity waste.

The cost estimates are based on work from References 5-9, particularly the study in Reference 7. The present estimates are judged to be accurate within $\pm$ 50%. This is reasonable given the limited scope of the project and it is consistent with the work in Reference 5.

Table 9. Comparison of Available Evaporators for Radioactive Liquid Waste Treatment (From Reference 6)

Evaporator	Major Advantage	Major Limitation	Suitable for Foamy CRNL Wastes
Coil	Low cost	Unsuitable for foaming liquids	No
Natural Circulation Tube or Vertical Tube	Relatively inexpensive	Unsuitable for foaming liquids	No
Forced Circulation	High heat transfer coefficient	Possible plugging of tube inlets	Yes
Thermosiphon	High heat transfer coefficient with dilute feeds	Concentration of high solids feed	Yes
Vapour Compression	High heat economics	Uneconomical for small flows	No

Table 9. Comparison of Available Evaporators for Radioactive Liquid Waste Treatment (From Reference 6) (continued)

Evaporator	Major Advantage	Major Limitation	Suitable for Foamy CRNL Wastes
Multiple effect	Same as vapour compression		No
Falling Film	Suitable for foaming liquids	Difficulty in achieving uniform feed distribution which leads to fouling	Yes
Rising Film	Suitable for foaming liquid	Can not handle large solids	No
Flash	Economical for large scale plant	Unsuitable for scaling liquids	No
Wiped Film	Suitable for foaming and scaling liquids	High evaporation cost	Yes

4. Technologies and Treatment Methods - GASEOUS EFFLUENTS

The gaseous emissions from a CANDU nuclear power plant, excluding tritium, may include:

- airborne particulate matter
- noble gases
- carbon-14
- iodine isotopes.

There are generally three sources of contaminated air:

- contaminated areas in the service building
- gaseous emissions from the spent fuel storage bay
- gaseous emissions from the reactor building.

The ventilation systems are designed to remove most of the radioactivity before the air is exhausted to the environment.

All radioactive emissions that are not trapped in the filter system are exhausted to the environment from the stack. The contaminated exhaust system may include [Ref. 14]:

1) filters for large particles.

2) HEPA (High Efficiency Particulate Air) filters with a 99.96% efficiency for particles 3 microns in size.

3) activated charcoal for radioiodine.

Filter trains are effective in removing the airborne radioactive particulates and the radioactive iodine. They are not effective for removing the noble gases or carbon-14. The technologies selected in this study for assessment of further reduction of emissions are the following:

1) additional filtering for iodine and particulates

2) charcoal delay beds for noble gases

3) calcium hydroxide absorber for carbon-14.

4.1 Assessment of Treatment Technologies

4.1.1 Iodine and Particulates

Radioiodine is released from failed fuel in the reactor core or spent fuel bay. Existing CANDU plants use filter trains for the treatment of exhaust air so as to reduce particulate and iodine emissions. The reference plants, Bruce A and Point Lepreau I, have filter trains.

There is no 'new' technology readily available to further reduce emissions. Nevertheless, more filters can be added to further reduce emissions. Since current emissions are routinely below the 'one percent-of-DEL' guideline, there has been no need to further reduce radioactive emissions.

In this study, the addition of more filters is treated as a 'new' technology. The addition of a second filter train would be expected to reduce the iodine emissions by a factor of 10, as for the first filter train.

There is no model of the particle size for the particulate emissions. They have passed through the first filter train and it is assumed that a second set of filters would have a proportionate effect. Note that if the particles were all 0.3 micron in diameter, the HEPA filters would give a DF = 2500. For the purpose of this study, a DF = 10 has been selected as giving a representative measure of the possible reduction.

Based on recent construction experience, the cost of a filter train in a single CANDU 600 MW(e) station would be about $150,000. For a 4 unit complex the estimated cost would be $500,000.

4.1.2 Noble Gases

The noble gases of interest are krypton, xenon and argon. Krypton-85 and xenon-133 are fission products which are released when fuel sheath failure occurs. Argon-41 is produced by neutron activation of natural argon.

The residence time of gases in the reactor building is approximately sixty hours. Any noble gases with half-lives less than 6 hours will have decayed to low levels before reaching the environment.

The radionuclides of concern are, therefore, Kr-85 with a half-life of 10.8 years and Xenon-133 with a half-life of 5.2 days.

The major source of noble gases in ventilation air is from the vents of vessels in which the coolant pressure is less than the operating pressure. These include:

1) the degasser
2) the D2O collection tank
3) the D2O storage tank
4) the fuelling machine purification tank.

Generally, a higher number of failed fuel sheaths corresponds to higher noble gas levels in the heat transport system and greater releases to the environment.

The proposed method for treating noble gases is through a charcoal delay bed [Ref. 5]. In the delay bed, the noble gas is held up for approximately 30 days. Xe-133 actually will be reduced by about 90 percent. Because of its long half-life, Kr-85 will be only slightly reduced.

The anticipated cost and performance of a charcoal delay bed system is summarized below.

(a) Point Lepreau II NGS

Gas flow rate = 20 m^3/h
Charcoal mass = 10 Mg
Capital cost = $8,000,000
Emission reduction factor = 10

(b) Darlington NGS

Gas flow rate = 80 m^3/h
Charcoal Mass = 35 Mg
Capital cost = $18,000,000
Emission reduction factor = 10.

Note that based on experience at Bruce A NGS [Ref. 10,12], the system may be less effective than assumed with a multi-unit containment.

The Off-Gas Management system that is part of the reference design for Darlington was not assessed in this study.

4.1.3 Carbon-14

Carbon-14 production rates are 3E10 Bq/MW/a with 95% of this being produced in the moderator. Emissions are estimated to be 3 percent of the amount generated [Ref. 11]. It is still uncertain whether the C-14 emissions are from the moderator system.

A calcium hydroxide absorber will reduce the concentrations in an air stream to 10 percent [Ref. 5]. For this study, it is assumed that a calcium hydroxide absorber installed in the moderator cover gas circuit will reduce emissions by a factor of 10 [Ref. 5]. For a CANDU 600, an estimated cost of $250,000 would be expected and $1 M for a 4 x 850 CANDU station.

The prototype CaOH container is expected to be 15 cm x 60 cm. Disposal cost at decommissioning would be negligible due to the small size of the unit.

It should be noted that the system is still in the prototype development stage and its effectiveness will not be known until the source of the C-14 is determined.

4.2 Summary of Treatment Technologies

Table 10 gives a summary of the cost and effectiveness of the technologies for reducing gaseous emissions. The systems are largely passive systems and will incur minimal additional operating costs. The annual cost is taken to be capital cost amortization in preparing Tables 1 and 2.

There is reasonable doubt that the charcoal delay beds and CaOH scrubbers will be as effective as projected. Thus, the estimated reduction factors should be treated with some caution until the technologies are proven to be as effective as assumed.

The estimated costs of the treatment technologies are judged to be accurate within $\pm$ 50 percent. This is reasonable given the limited scope of the project and it is consistent with the work in Reference 5.

Table 10. Summary of Treatment Technologies for Gaseous Emissions

Contaminant	Technology	Reduction Factor for Emissions	Cost in 1987 Dollars Pt. Lepreau	Darlington
Airborne Particulates	Double Filter Train	10	$0.15 M	$ 0.5 M
Iodine Isotopes	Double Filter Train	10	0.15 M	0.5 M
Carbon-14	CaOH Scrubber	10	0.25 M	1 M
Noble Gases	Charcoal Delay Bed	10	8 M	18 M

5. Pathway Models and Detriment Calculations

The technologies that have been discussed in Sections 2, 3 and 4 for reducing emissions were further assessed for the effect on the detriment [Ref. 1] attributed to the two reference nuclear power stations.

The model for assessing the detriment of the generation stations is shown in Figure 1. The nuclear power plant licencees control the radioactive liquid and gaseous emissions to stay within derived emission limit guidelines. These limits are based on an acceptable dose to the population near the plant, usually within 75 Km. In this study, the detriment is to include the effect of trace elements that are long-lived. That is, the radionuclides C-14 (5730/a) and I-129 (1.6 E7/a). It is also to include the global collective committed dose to which H-3 (12.3/a) and Kr-85 (10.8/a) contribute as well.

This section summarizes the models used in the assessment of detriment and the results of the detriment calculations.

5.1 Pathway and Dose Models

A literature review was undertaken to obtain information and models that could be applied in the assessment of the global dose commitment. The relevant articles and reports are listed in the Bibliography. Three conclusions can be drawn from the literature review:

1) There is a large volume of models and other information for assessing individual exposures near the plant (within 100 Km).

2) There is very little detailed modelling of the global detriment due to long-lived radionuclides that can be applied directly in this study.

3) There is very little literature on the assessment of environmental pathways on a regional scale (within 1-2000 Km) where there is a non-uniform distribution of radionuclides over the region. No models were found that could be made specific to the Point Lepreau and Darlington sites within the scope of the study.

5.1.1 Model for Local Dose Calculation

The model chosen for the calculation of doses in the area local to the power plants is the pathway dosimetric model given in CSA N288.1 Draft #5 [Ref. 2]. Other models were reviewed (e.g. USNRC Regulatory Guide 1.109 and others reported in the Bibliography) but the CSA guidelines were accepted as being adequate for this study. It is routinely used

by Canadian utilities to calculate the derived emission limits for the nuclear power plants.

The environmental pathway model is shown in Figure 5.

The transport of radionuclides is described by compartment values Xi and transfer parameters Pij. The transfer parameters are site specific and radionuclide specific. The values used for the transfer parameters are tabulated in Appendix D.

With this model, the individual dose (compartment 9) in the local area is calculated on an annual basis (Sv/a). The calculation of the dose can be reduced to expressing the dose X9 in terms of the emission source X0 (Bq/s), or the gaseous (X1) and liquid (X2) emissions separately.

One of the main reasons for using the CSA model is that it incorporates site specific data that are readily available in Safety Reports and DEL Reports. These reports were obtained from the AECB and site specific data incorporated wherever possible. Appendix B gives the site specific data used.

In the CSA standard generic model, parameters have been conservatively selected. Conservative values for the transfer parameters are in the direction of overestimating the dose. For this study a conservative dose estimate results in an overestimate of the dose reduction or effectiveness of a technology.

5.1.2 Model for Regional Dose Calculations

A regional model for dose calculations would be intermediate between the local model (5.1.1) and the global model (5.1.3). It would incorporate non-uniform exposures of the population beyond the local region. No applicable models were found in the literature. Thus, the assessment of detriment beyond the local region is given by the global model only.

5.1.3 Model for Global Dose Calculations

The only complete model for assessing global detriment due to long-lived radionuclides was found to be that prepared by the NEA Group of Experts [Ref. 3]. This model treats the global dispersion of H-3, C-14, Kr-85 and I-129.

In the NEA model the collective effective dose equivalent is as in (5.1.1) with the addition of two terms. The additional effects are the following:

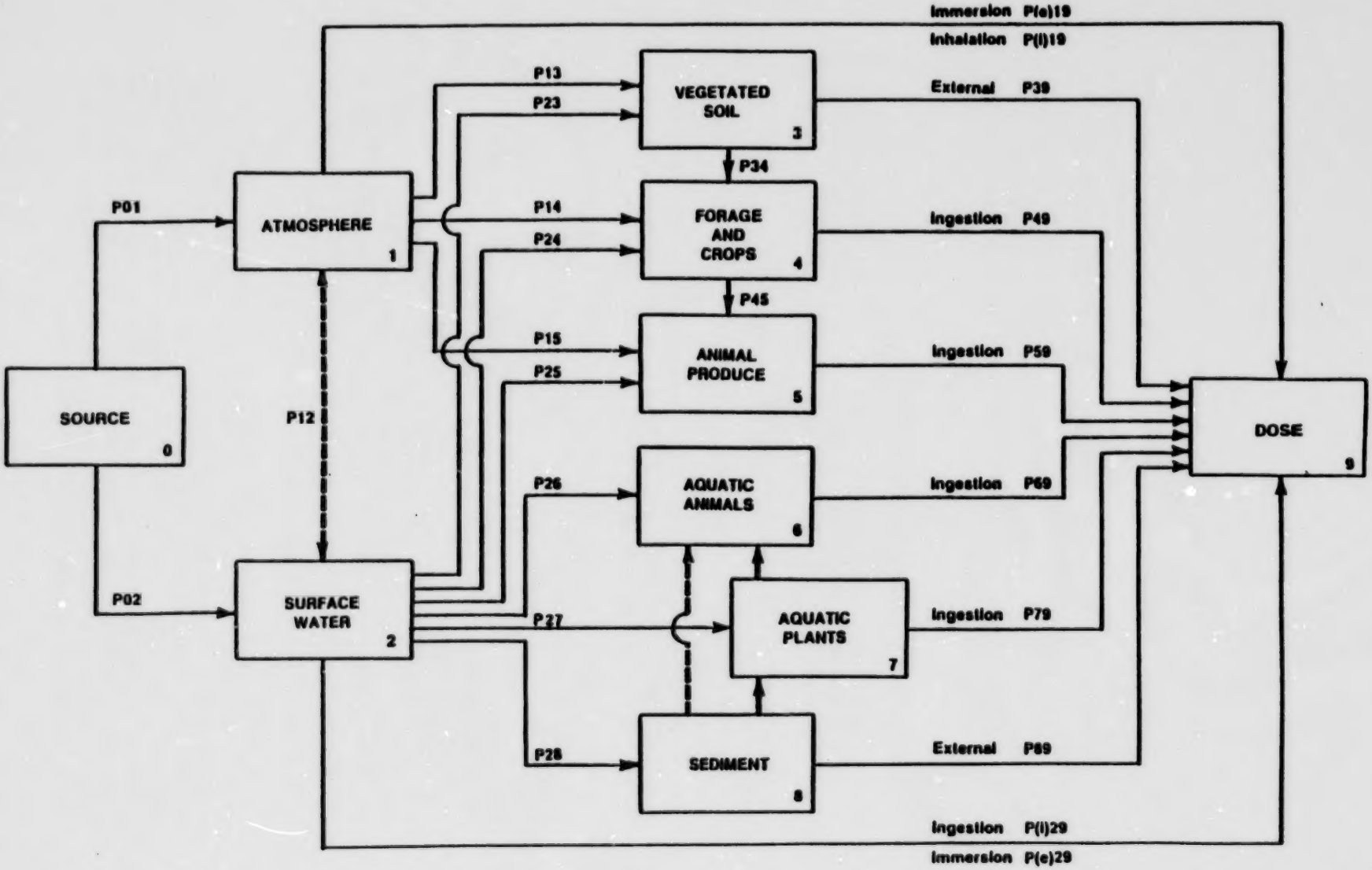


Figure 5. Environmental Pathway Model

(1) a genetic effect that is 25 percent of the gonad exposure

(2) a fatal skin cancer effect that is 1 percent of the skin exposure.

The model assumes a static world population of 10 billion people and the detriment is assessed for 10,000 years into the future.

The NEA model is readily applied to the current assessment since it gives the collective dose equivalent commitments per unit emission (for H-3, C-14, Kr-85 and I-129).

5.2 Source Terms for Reference Power Plants

The source terms used as reference rates of radionuclide emission in this study are given in Table 11. These emission rates were developed from information in Reference 4 and as noted below.

The following assumptions were made in developing the source terms:

1. The measured releases were not combined with the plant operating history to obtain a reference emission rate for 100 percent capacity factor. Thus the annual emission rates are deemed to represent an average capacity factor and the anticipated range of operating conditions including upset transients.

2. The I-129 emission rate was taken to be in the same fraction of the I-131 emission rate as the relative fission yields of the two isotopes.

3. For gaseous effluents the release rates are given in Bq/s (Bq-MeV/s for noble gases) in a constant ventilation in discharge.

4. For liquid effluents the release rates are calculated as concentrations in Bq/L of the radionuclide in the liquid wastes discharged from the station liquid waste management system. A constant annual volume is assumed for each site. For Point Lepreau II the discharge rate is 30,000 m^3/a and for Darlington it is 45,000 m^3/a. The source term also incorporates the additional liquid volume from the station outfall (PO2).

5. The variety and concentrations of metallic radionuclides in liquid effluents varies widely with operating conditions at a particular station. Also, liquid effluents are released in a batch fashion. These two factors make it difficult to estimate an average emission rate for any particular radionuclide. The most restrictive radionuclide in terms of detriment was assumed to be the sole component of the emission for this group of radionuclides. Zn-65 and Co-60 are the selected radionuclides for Point Lepreau II and Darlington, respectively.

Table 11. Source Terms for the Reference Sites

	Point Lepreau II		Darlington	
Nuclide	To Air Bq/s	To Water** Bq/L	To Air Bq/s	To Water** Bq/L
Carbon-14	2.15 E4	0	1.2 E5	0.02
Tritium (as oxide)	6.15 E6	54	6.3 E7	2.3 E2
Iodine-129	6.6 E-10	0	3.2 E-8	0
Iodine-131	0.131	NA	6.3	0.02
Zinc-65	0	4.6 E-3	NA	NA
CO-60	NA	NA	0	0.02
Noble Gases*	2.54 E4	0	2.54 E7	0
Particulates	NOT DETECTED	0	2.2	0

*Note: Figures for Noble Gases are in Bq-MeV/s, not Bq/s.

**The liquid effluent source terms include a dilution factor due to the addition of the Condenser Cooling Water, i.e. the PO2 term.

Average concentrations for these nuclides were calculated based on the average gross beta-gamma liquid effluent concentrations. This is a conservative assumption and it should be borne in mind that dose detriments from metallic nuclides ('beta-gamma emitters') will be overestimated.

6. For particulate emissions there are no reference data for Point Lepreau. For Darlington the particulate emission is treated as a Co-60 emission for the same reasons as given in item 5 above.

7. The emission rate for C-14 is assumed to be 3 percent of the estimated production rate [Ref. 11].

5.3 Results of Detriment Calculations

5.3.1 Results for the Local Pathways

Appendix B gives details of the individual dose calculation for the local population. In brief, the following assumptions are made:

a) The local region is subdivided by radii and concentric circles and the entire population of each compartment is located at its centre.

b) The emission rates are averages over a year. This assumes a continuous as opposed to batch mode of releasing activity into the environment.

c) For unknown mixed radionuclide releases, the most restrictive radionuclide is assumed to be present.

The detriment is calculated in the following sequence:

(1) Individual dose equivalent rate is calculated for each compartment in the local area.

(2) The collective effective dose equivalent commitment is calculated assuming a constant individual dose rate for a 50 year period and a constant population for each compartment.

Tables 12 and 13 give the reference local collective doses for the two sites. For the liquid effluents the limiting radionuclide is assessed. Also, the particulate emissions from Darlington are assumed to have all the activity as Co-60.

Tables 14 and 15 give the reduction in local collective dose from the application of liquid effluent reduction technologies. The four cases considered are those discussed in Section 3, Tables 7 and 8.

Tables 16 and 17 give the reduction in local collective dose from the application of detritiation technologies as discussed in Section 2.

Tables 18 and 19 give the reduction in local collective dose from the application of reduction technologies for the gaseous emissions. The 50 year cost is from the estimates in Section 4.

5.3.2 Results for the Global Pathways

The NEA model was used to calculate the global detriment from the release of H-3, C-14, I-129 and Kr-85. The model defines a collective dose equivalent commitment per unit of emission (Person-Sv/TBq). Using the NEA global dose factors with the source terms from Table 11, the global collective doses have been calculated and the results are summarized in Tables 20 and 21. Appendix C gives further details on the application of the NEA model.

5.3.3 Accuracy of Dose Calculations

The local dose calculations are based on pathway models that use conservative assumptions for most of the parameters. The effect of these assumptions is not quantified. However, we expect the pathway model is likely conservative by a factor of about 10. In addition, we have made conservative assumptions in modelling the effect of the treatment technologies. The overall effect then would be to give predicted reductions in local dose detriments that are high by at least an order of magnitude.

In Reference 3, it is estimated that the global dose factors are likely high by a factor of 5-10. These dose factors are then combined with the world population which has not been modelled at all. Thus, the accuracy of the predicted reduction in global dose cannot be assigned. Given the population model, the predicted reductions are likely high by the factor of 5-10.

5.4 Reduction in Detriment from Application of New Technologies

The net effect of the application of a new technology can be obtained by adding the local and global collective dose equivalent commitments from Tables 14-21. This has been done and reported in Tables 1 and 2, for each of the technology options.

Table 12. Reference Collective Dose at Pt. Lepreau II (Person-Sv)

	Collective Dose (Person-Sv)			
Radionuclide	Atmosphere	Liquid	Total	% of total
Tritium	0.6090 E-1	0.5680 E-2	0.666 E-1	79
Carbon-14	0.2318 E-2	ND	0.2318 E-2	3
Iodine-131	0.1795 E-5	NA	0.1795 E-5	<0.2
Iodine-129	0.5690 E-12	NA	0.5690 E-12	<0.0001
Zinc-65 (liquid)	NA	0.1443 E-1	0.1443 E-1	17
Particulates	ND	NA	ND	-
Noble Gases	0.1203 E-2	NA	0.1202 E-2	1
Total			0.8395 E-1	

ND = Not Detected
NA = Not Applicable

Table 13. Reference Collective Dose at Darlington (Person-Sv)

Radionuclide	Collective Dose (Person-Sv) Atmosphere	Liquid	Total	% of total
Tritium	6.645	8.925	15.57	44
Carbon-14	0.1649 E-2	0.1999 E-1	0.2163 E-1	$\leq$0.06
Iodine-131	0.2630 E-3	NA	0.2630 E-3	$\leq$0.0007
Iodine-129	1 E-11	NA	1 E-11	0
Co-60 (liquid)	NA	6.74	6.74	19
Particulates (CO-60)	0.1116 E-2	NA	0.1116 E-2	$\leq$0.003
Noble Gases	13.06	NA	13.06	37
Total			35.39	

NA - Not Applicable

Table 14. Reduction in Collective Dose from Application of Liquid Waste Technologies for Pt. Lepreau II

Technology	Collective Dose* (Person-Sv)	Cost**	% Reduction
No Treatment	0.8395 E-1	-	-
Filtration	0.7529 E-1	$0.1 M	10
Filt. + IX	0.7031 E-1	$10 M	16
Filt. + IX + Evap.	0.6952 E-1	$80 M	17
Evaporation	0.6952 E-1	$50 M	17

*Assumes all activity in liquid waste streams is Zinc-65.

**Cost is estimated 50 year total cost.

Table 15. Reduction in Collective Dose from Application of Liquid Waste Technologies for Darlington

Technology	Collective Dose* (Person-Sv)	Cost**	% Reduction
No Treatment	35.39	-	-
Filtration	32.27	$0.15 M	9
Filt. + IX	28.96	$16 M	18
Filt. + IX + Evap.	28.62	$120 M	19
Evaporation	28.63	$75 M	19

*Assumes all activity in liquid waste streams is Co-60.

**Cost is estimated 50 year total cost.

Table 16. Reduction in Collective Dose from Tritium Technology at Pt.Lepreau II

	H-3 Dose	Total Dose (Person-Sv)	Total Cost (50 Year)	% Reduction
No Treatment	0.660 E-1	0.8395 E-1	-	-
Detritiation*	0.222 E-1	0.3955 E-1	$192 M	53

*A reduction factor of 3 is assumed for detritiation.

Table 17. Reduction in Collective Dose from Tritium Technology at Darlington

	H-3 Dose	Total Dose (Person-Sv)	Total Cost (50 Year)	% Reduction
No Treatment	15.57	35.39	-	-
Detritiation*	5.19	25.01	$240 M	29

*A reduction factor of 3 is assumed for detritiation.

Table 18. Reduction in Collective Dose from Air Emission - Pt. Lepreau II

Total Dose without New Technology = 0.8395 E-1 Person-Sv

Radionuclide	Technology	Collective Dose	Total Cost	% Reduction
Iodine + Particulates	2 x Filters	0.8395 E-1	$0.15 M	2 E-3
C-14	Ca(OH)Scrubber	0.8186 E-1	$0.25 M	2
Noble Gas	Charcoal Bed	0.8287 E-1	$8 M	1

Table 19. Reduction in Collective Dose from Air Emission - Darlington

Total Dose without New Technology = 35.39 Person-Sv

Radionuclide	Technology	Collective Dose	Total Cost	% Reduction
Iodine + Particulates	2 x Filters	35.39	$0.5 M	3 E-3
C-14	Ca(OH)Scrubber	35.37	$1 M	6 E-2
Noble Gas	Charcoal Bed	23.64	$18 M	33

Table 20. Global Collective Dose Commitment from Pt. Lepreau II

Radionuclide	Collective Dose (Person-Sv) Without Technology	With Technology	% Reduction
H-3	7.05	2.35	0.2
C-14	2.68 E3	2.68 E2	90
I-129	8.4 E-12	8.4 E-13	<0.01
Kr-85	3.6 E-3	3.6 E-4	<0.01
Total	2.69 E3	2.70 E2	90%

Table 21. Global Collective Dose Commitment from Darlington

Radionuclide	Collective Dose (Person-Sv) Without Technology	With Technology	% Reduction
H-3	87.0	29	0.4
C-14	1.5 E4	1.5 E3	89
I-129	4.1 E-10	4.1 E-11	<0.01
Kr-85	0.36	0.36 E-1	<0.01
Total	1.51 E4	1.53 E3	90%

6. Conclusions

Selected technologies that can be applied to further reduce radioactive emissions from CANDU nuclear power plants have been assessed. The cost of the technologies and the effect on the total dose detriment have been estimated for Darlington and Point Lepreau as reference sites. The results are summarized in Tables 1 and 2.

The estimates of reduction in dose should be treated with circumspection for the following reasons:

(1) The pathway modelling for calculating dose is incomplete. No regional pathway model was found that would be directly applicable to the two reference sites. This deficiency is likely greatest for doses from H-3 and I-129.

(2) The local pathway models use conservative assumptions for default parameters. This will cause an overestimate of the potential dose reduction by as much as a factor of 10.

(3) The global pathway modelling is conservative by a factor of 5-10. Further, the population dynamics that would contribute to the collective dose from long-lived radionuclides is not modelled.

Overall, we judge the cost estimates to be accurate within a factor of 2 and the predicted dose reductions to be high by as much as a factor of 10.

7. References

1. "Recommendations of the International Commission on Radiological Protection," ICRP Publication 26, January 17, 1977, Published for the ICRP by Pergammon Press, New York.

2. CSA Standard CAN3-N288.1, "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities," Draft #5 (unpublished).

3. "Radiological Significance and Management of Tritium, Carbon-14, Krypton-85, Iodine-129 Arising from the Nuclear Fuel Cycle," Report by an NEA Group of Experts, NEA/OECD, April 1980.

4. AECB Information Report INFO-0210 Radioactive Release Data from Canadian Nuclear Power Stations 1972-1985, September 1986.

5. Review of Technologies to Control Radioactive Airborne Emissions from CANDU Stations, Final Report, London Nuclear Report 855.101.1, 1985.

6. Radioactive Liquid Wastes from Steam Electric Generating Stations. (Draft No. 3) Discussion paper prepared for Working Group 5(2) "Radioactivity" Task Force Environmental Codes of Practice for Steam Electric Power Generation. Environment Canada, 1982.

7. Kenchington, J.M., Stewart, W.B., Drolet, T.S., An Evaluation of Liquid Radioactive Waste Treatment Systems for Canada PHW Reactors ASME 78-JPGC-NE-17, 1979.

8. Furlow, R.H. and Dryden, C.E., Chemical Engineering Costs, Ohio State University, Columbus, Ohio, 1966 Edition.

9. Chemical and Mineral Process Plant Price Indexes.

10. Chek, C.H., "Review of Gas Treatment Systems for Nuclear Facilities," AECL TR-224, March 1984.

11. Guest, A. and Maruska, T., Monitoring of Airborne C-14 Emissions from Ontario Hydro Nuclear Generating Stations. Paper presented at the CRPA Conference, Toronto, Ontario, 1983.

12. Carter, T.J. Radioactive Waste Management Practices at a Large Canadian Electric Utility, IAEA-SA-57/1, 1981.

8. Bibliography

AECB, "Regulatory Objectives, Requirements and Guidelines for the Disposal of Radioactive Wastes - Long-Term Aspects," Regulatory Document R-104, June 5, 1987.

AECB, "Regulatory Objectives, Requirements and Guidelines for the Disposal of Radioactive Wastes," Consultative Document C-104, April 30, 1986.

AECB, "The Determination of Effective Doses from the Intake of Tritiated Water," Consultative Document C-100, September 17, 1986.

ApSimon, H.M., Goddard, A.J.H. and Wrigley, J., "Long-Range Atmospheric Dispersion of Radioisotopes - I. The Mesos Model," Pergamon Press, November 1983.

ApSimon, H.M., Goddard, A.J.H., Wrigley, J. and Crompton, S., "Long-Range Atmospheric Dispersion of Radioisotopes - II. Application of the Mesos Model," Pergamon Press, 1985.

Beamer, N.V., "Experience with Low-Level Waste Incineration at Chalk River Nuclear Laboratories," AECL-8187, March 11-15, 1984.

Beamer, N.V., Bourns, W.T., Buckley, L.P., Pettipas, W.H., Burrill, K.A., Dixon, D.F. and Charlesworth, D.H., "Studies of Reactor Waste Conditioning and Disposal at CRNL," AECL-7551, September 1982.

Bentley, B.W., "Comparison of the Radiation Dose to the General Public with Fenceline Doses at Nuclear Facilities," HEDL-SA-494, December 7, 1972.

Bonka, H., "Production and Emission of Tritium from Nuclear Facilities, and the Resulting Problems," IAEA-SM-232/12.

Bonka, H., Grundler, D. and Horn, H.-G., "Problems Occurring While Carrying Out Cost-Benefit Analysis for H,C-14, Kr-85, Iodine and Aerosols in Nuclear Facilities," IAEA-SR-36/14.

Bourns, W.T., "Reverse Osmosis Plant to Process CRNL Low Level Radioactive Liquid Wastes," AECL-7337, June 1981.

Bryant, Pamela M., "Review of Radionuclides Released from the Nuclear Fuel Cycle and Methods of Assessing Dose to Man," IAEA-SM-237/75.

Buchanan, J.R., "Technical Note: The Use of the Annual Average Radiation Dose for Risk Comparison Purposes," Nuclear Safety, Vol. 26, No. 4, July-August 1985.

Buckley, L.P. and Burt, D.A., "Purification and Solidification of Reactor Wastes at a Canadian Nuclear Generating Station," AECL-7240, June 1981.

Burnham, Peter, "The Derived Emission Limits of Radionuclides in the Airborne and Liquid Effluents from Darlington Nuclear Generating Station A," SSD-86-1.

Bush, R.P. and others, "Carbon-14 Waste Management," EUR-8749, 1984.

Bush, R.P., "Carbon-14 Waste Management - A Review," IAEA-CN-43/26.

Cardito, J.M. and Mazzola, C.A., "Some Problems Associated with Near-Real-Time Offsite Dose Assessment."

Carter, T.J., "Radioactive Waste Management Practices at a Large Canadian Electrical Utility," IAEA-SR-57/1, October 5-9, 1981.

Carter, T.J. and Rao, P.K.M., "Fifteen Years of Radioactive Waste Management at Ontario Hydro," Proceedings, U.S.D.O.E. Low Level Waste Management Program, September 11-14, 1984.

Carter, T.J. and Rao, P.K.M., "Ontario Hydro's Systems Approach to Radioactive Materials Management," Proceedings, 3rd International Conference on Nuclear Technology Transfer ICONTT III, October 14-18, 1985.

Charlesworth, D.H., "Low- and Intermediate-Level Waste Management Practices in Canada," AECL-7629, May 1982.

Clark, M.J., Grimwood, P.D. and Camplin, W.C., "A Model to Calculate Exposure from Radioactive Discharges into the Coastal Waters of Northern Europe," NRPB-R109, November 1980.

Clarke, R.H., Goddard, A.J.H. and Fitzpatrick, J., "The Prediction of Population Doses Due to Radioactive Effluents from Nuclear Installations," IAEA-SM-184/8, 1974.

Clarke, R.H., "A Model for Short and Medium Range Dispersion of Radionuclides Released to the Atmosphere," NRPB-R91, September 1979.

Clarke, R.H. and Webb, G.A.M., "Methods for Estimating Population Detriment and Their Application in Setting Environmental Discharge Limits," IAEA-SM-237/6.

CNS, "International Conference on Radioactive Waste Management," INIS-mf-9040, 1982.

CSA, "CSA Technical Committee (N288) on Environmental Radiation Protection," CSA N288.1.(Draft - to be published)

CSA, "Radiological Monitoring of the Environment," CSA Standard N288.4, June 1986.(Draft - to be published)

Das Gupta, A.K., Taniguchi, H. and Measures, Mary P., "Canadian Experience in Assessing Population Exposures from CANDU Reactors," IAEA-SM-184/42, 1974.

Dichev, G., Khitov, G., Shraiter, V., Volkov, V.F. and Sedov, V.K., "Radiation safety of Commercial Nuclear Power Stations with VVER-440," Atomnaya Energiya, Vol. 50, No. 2, pp. 99-102, May 20, 1980.

Duursma, E.K., "Specific Activity of Radionuclides Sorbed by Marine Sediments," BNWL-SA-4330, May 1972.

Edelhauser, H., Bonka, H., Gans, I., Huber, O., Vogt, K.J. and Wolter, R., "Radioactive Effluents and Present and Future Radiation Exposure to the Population from Nuclear Facilities in the Federal Republic of Germany," IAEA-CN-36/557, May 2-13, 1977.

Flanigan, J.A., "Pre-Operational Environmental Radiation Monitoring Data for Point Lepreau Generating Station," Report NBEPC-HP-80-1, September 1980.

Flanigan, J.A. and Paciga, J.J., "Operational Environmental Radiation Monitoring Program for Point Lepreau Generating Station," Report NBEPC-HP-79-2, September 1979.

Flanigan, J.A. and Paciga, J.J., "Pre-Operational Environmental Radiation Monitoring Data for Point Lepreau Generating Station," Report NBEPC-HP-79-1, September 1979.

French Industrial Experience, "Radioactive Waste Management Decommissioning Spent Fuel Storage," Vol. 2, Waste Processing and Conditioning, February 1985.

Gorman, D.J., "The Basis for the Derived Limits for the Emission of Radionuclides in Airborne and Liquid Effluents from Ontario Hydro's Nuclear Facilities," Ontario Hydro Safety Services Department, March 1986.

Gorman, D.J. and Wong, K.Y., "Environmental Aspects of Tritium from CANDU Station Releases," IAEA-SM-232/49.

Gorman, D.J., "The Basis for the Derived Limits for the Emission of Radionuclides in Airborne and Liquid Effluents from Ontario Hydro's Nuclear Facilities," Ontario Hydro, November 1983.

Greening, F.R., Sood, S.P. and Dodd, D.J.R., "Carbon-14 Characterization - Interim Report," Report No. 87-9-K, January 12, 1987.NBEPC, "Point Lepreau Generating Station Derived Emission Limits for Radionuclides in Gaseous and Liquid Effluents," NBEPC-HP-76-1.

Guest, A. and Maruska, R., "Monitoring of Airborne C-14 Emissions from Ontario Hydro Nuclear Generating Stations," CRPA Conference, May 3-5, 1983.

Hardy, D.G. and Dixon, D.F., "The Transition from Storage to Permanent Disposal of Low- and Intermediate-Level Wastes at the Chalk River Nuclear Laboratories," AECL-8728, Proceedings, Waste Management '85, March 24-28, 1985.

Holtslander, W.J., Drolet, T.S. and Osborne, R.V., "Recovery of Tritium from CANDU Reactors, Its Storage and Monitoring of Its Migration in the Environment," AECL-6544, July 1979.

Holtslander, W.J. and Yaraskavitch, J.M., "Tritium Immobilization and Packaging Using Metal Hydrides," AECL-7151, April 1981.

Hunt, G.J., "Radioactivity in Surface and Coastal Waters of the British Isles," INIS-mf-6782, 1981.

IAEA, "Generic Models and Parameters for Assessing the Environmental Transfer of Radionuclides from Routine Releases," Safety Series No. 57, 1982.

IAEA, "Treatment of Low- and Intermediate-Level Liquid Radioactive Wastes," Technical Reports Series No. 236, 1984.

IAEA, "Tritium in Some Typical Ecosystems," Technical Reports Series No. 207, 1981.

IAEA, "Conditioning of Low- and Intermediate-Level Radioactive Wastes," Technical Report Series No. 222, 1983.

IAEA, "Management of Tritium at Nuclear Facilities," Technical Report Series No. 234, 1984.

IAEA, "Control of Iodine in the Nuclear Industry," Technical Reports Series No. 148, 1973.

IAEA, "Principles for Limiting Releases of Radioactive Effluents into the Environment," Safety Series No. 77, 1986.

IAEA, "Design Aspects of Radiation Protection for Nuclear Power Plants," Safety Series No. 50-SG-D9, 1985.

IAEA, "Assigning a Value to Transboundary Radiation Exposure," Safety Series No. 67, 1985.

IAEA/NEA, "Optimization of Radiation Protection," Vienna, March 10-14, 1986.

IAEA, "Separation, Storage and Disposal of Krypton-85," Technical Reports Series No. 199, 1980.

IAEA/WHO, "Population Dose Evaluation and Standards for Man and His Environment," Portoro, May 20-24, 1974.

IAEA/WHO/UNEP, "Risks and Benefits of Energy Systems," Julich, April 9-13, 1984.

IAEA, "Risk Evaluation for Protection of the Public in Radiation Accidents," Safety Series No. 21, 1967.

IAEA, "Principles for Establishing Limits for the Release of Radioactive Materials into the Environment," Safety Series No. 45, 1978.

IAEA, "Basic Safety Standards for Radiation Protection," Safety Series No. 9, 1982.

IAEA, "Risk Evaluation for Protection of the Public in Radiation Accidents," Safety Series No. 21, 1967.

IAEA, "Control of Iodine in the Nuclear Industry," Technical Report Series No. 148, 1973.

IAEA/OECD, "Management of Radioactive Wastes from Fuel Reprocessing," Paris, 1972.

ICRP, "Principles of Environmental Monitoring Related to the Handling of Radioactive Materials," ICRP Publication 7, Pergamon Press, 1975.

ICRP, "Radionuclide Release into the Environment: Assessment of Doses to Man," ICRP Publication 29, Pergamon Press, October 1978.

ICRP, "Implications of Commission Recommendations that Doses Be Kept as Low as Readily Achievable," ICRP Publication 22, Pergamon Press, April 1973.

ICRP, "Annals of the ICRP," ICRP Publication 26, Pergamon Press, January 17, 1977.

Isaac, H.N. and Rao, P.K.M., "Management of Low and Intermediate Level Nuclear Wastes at Ontario Hydro," Symposium on Alternative Low Level Waste Technologies, February 27-March 1, 1986.

Johnson, J.R., Stewart, D.G. and Carver, M.B., "Committed Effective Dose Equivalent Conversion Factors for Intake of Selected Radionuclides by Infants and Adults," AECL-6540, November 1979.

Johnson, J.R. and Dunford, D.W., "Dose Conversion Factors for Intakes of Selected Radionuclides by Infants and Adults," AECL-7919, January 1983.

Jones, J.A., "Modelling Wet Deposition from a Short Release," NRPB-R198, August 1986.

Jones, J.A. "A Procedure to Include Deposition in the Model for Short and Medium Range Atmospheric Dispersion of Radionuclides," NRPB-R122, September 1981.

Jones, J.A., "A Model for Long Range Atmospheric Dispersion of Radionuclides Released Over A Short Period," NRPB-R124, November 1981.

Jones, J.A., "The Uncertainty in Dispersion Estimates Obtained from the Working Group Models," NRPB-R199, August 1986.
Jones, J.A., "The Estimation of Long Range Dispersion and Deposition of Continuous Releases of Radionuclides to Atmosphere," NRPB-R123, October 1981.

Kabat, M.J., "Monitoring of Gaseous Effluents in Ontario Hydro," Proceedings IAEA, 1978.

Kibbey, A.H. and Godbee, H.W., "A State-of-the-Art Report on Low-Level Radioactive Waste Treatment," ORNL/TM-7427, September 1980.

Lawson, G. and Smith, G.M., "Bios: A Model to Predict Radionuclide Transfer and Doses to Man Following Releases from Geological Repositories for Radioactive Wastes," NRPB-R169, January 1985.

LeSurf, J.E., Charlesworth, D.H. and Isaac, H.N., "Processing, Storage, and Disposal of Low- and Intermediate-Level Waste in Canada," AECL-8347, March 11-15, 1984.

London Nuclear, "Review of Technologies to Control Radioactive Airborne Emissions from CANDU Stations," Report 855.101.1, Vols 1,2,3 Technical Report, March 1985.

Maan, M.A., "Cost Effective Radiation Risk Management in a Generic Nuclear Plant Design," AECL-7536, November 1982.

Martin, James A. Jr., "Calculations of Environmental Radiation Exposures and Population Doses Due to Effluents from a Nuclear Fuel Reprocessing Plant," Radiation Data and Reports, February 1973.

Martin, James A., Jr., et al., "A Computer Code (RVRDOS) to Calculate Population Doses from Radioactive Liquid Effluents, Etc...," ORP/EAD-76/4, October 1976.

Masschelein, W.J, and Genot, J., "Impact of Nuclear Power Plants of the PWR-Type on River Water Quality (Case Report of the River Meuse)," Wat. Sci. Tech. Vol. 14, Capetown, pp. 199-214, 1982.

Miller, Charles W., "Models for Environmental Radiological Assessments," U.S. Department of Energy, 1984.

Nakayama, Y., Shirai, T., Hashimoto, H., Kamiya, Y., Sasaki, S., Kadoya, S., Nomi, M., Kawazu, H., Sugimoto, S. and Sakaki, T., "New Techniques for the Treatment of Laundry and Other Low-Level Liquid Wastes," IAEA-SM-207/15.

NCRP, "Krypton-85 in the Atmosphere - Accumulation, Biological Significance, and Control Technology," NCRP Report No. 44, 1975.

NCRP, "Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment," NCRP Report No. 76, 1985.

NCRP, "Carbon-14 in the Environment," NCRP Report No. 81, 1985.

NCRP, "Iodine-129: Evaluation of Releases from Nuclear Power Generation," NCRP Report No. 75, December 1, 1983.

NCRP, "Krypton-85 in the Atmosphere - With Specific Reference to the Public Health Significance of the Proposed Controlled Release at Three Mile Island," NCRP, May 16, 1980.

NEA, "Monitoring of Radioactive Effluents," Proceedings, 1974.

NEA, "Iodine 129," Paris, 1977.

NEA, "Radiological Significance and Management of Tritium, Carbon-14, Krypton-85, Iodine-129 Arising from the Nuclear Fuel Cycle," April 1980.

Ng, Y.C., Colsher, Carolyn S. and Thompson, S.E., "Transfer Factors for Assessing the Dose from Radionuclides in Agricultural Products," IAEA-SM-237/54.

NUREG-0472/0473, "Radiological Effluent Technical Specifications," Rev. 2, July 18, 1979.

NUREG-0473, "Radiological Effluent Technical Specifications for La Salle County Station, Units 1 and 2," Rev. 2, August 1979.

NUREG/CR-3665-EX SUM, "Optimization of Public and Occupational Radiation Protection at Nuclear Power Plants," SAIC-84/1317, September 1984.

NUREG/CR-3665-V1, "Optimization of Public and Occupational Radiation Protection at Nuclear Power Plants. A Review of Occupational Dose Assessment Considerations in Current Probabilistic Risk...," SAI-83/1125-Vol-1, September 1984.

NUREG/CR-3665-V2, "Optimization of Public and Occupational Radiation Protection at Nuclear Power Plants. Considerations in Factoring Occupational Dose into Value-Impact and Cost-Benefit Analyses," SAI-84/1010-Vol-2, September 1984.

NUREG/CR-3665-V3, "Optimization of Public and Occupational Radiation Protection at Nuclear Power Plants. A Calculation Method," SAI-84/3037-Vol-3, September 1984.

Oak Ridge National Lab, "Low-Level Radioactive Waste Treatment Technology," Low-Level Radioactive Waste Management Handbook Series, DOE/LLW-13Tc, July 1984.

Ontario Hydro, "Chemical Research Department Quarterly Progress Report for January - March 1986," Report No. X86-16-R, April 30, 1986.

Ontario Hydro, "Chemical Research Department Quarterly Progress Report for April - June, 1986," Report No. X86-32-R, July 25, 1986.

Ontario Hydro, "The Tritium Control Working Party Report," September 1978.

Palmer, J.F., "Derived Release Limits (DRL's) for Airborne and Liquid Effluents from the Chalk River Nuclear Laboratories during Normal Operations," AECL-7243, February 1981.

Pence, D.T., "Critical Review of Noble Gas Recovery and Treatment Systems," Nuclear Safety, Vol. 22, No. 6, November-December 1981.

Peterson, Harold T., Jr., "Stable Element and Radionuclide Reconcentration in Aquatic Ecosystems - I. Stable Element Effects in the Equilibrium Situation," Health Phys. Aspects of Nuclear Facility Siting, Idaho, November 3-6, 1970.

Pochin, Edward E., "Estimated Population Exposure from Nuclear Power Production and Other Radiation Sources," NEA, January 1976.

Protert, R., "Options for Reducing Tritium in Heavy Water Process Systems," IAEA-SM-286/52.

Province of New Brunswick, "Second Nuclear Reactor Point Lepreau, New Brunswick - Report of the Environmental Assessment Panel," Cat. No. En 105-33/1985.

Rummery, T.E., Lisle, D., Howieson, J. and Charlesworth, D.H., "Radioactive Waste Management Policy and Its Implementation in Canada," IAEA-CN-43/165, May 16-20, 1983.

Soldat, J.K., Baker, D.A. and Corley, J.P., "Applications of a General Computational Model for Composite Environmental Radiation Doses," IAEA-SM-172/82.

Statistics Canada, Demography Divisions, "Postcensal Estimates of Population and Components of Growth by Sex and Age for Canada, Provinces and Territories," June 1, 1986.

Sutcliffe, W.G., "Uncertainty Analysis: An Illustration from Nuclear Waste Package Development," Nuclear and Chemical Waste Management, vol. 5, pp. 131-140, Pergamon Press, 1984.

Sutherland, J.K., "Environmental Radiation Monitoring Data for Point Lepreau Generating Station," Report HP-07000-86-1, NBEPC, March 1986.

Sutherland, J.K., "Environmental Radiation Monitoring Data for Point Lepreau Generating Station," Report HP-07000-87-1, NBEPC, February 1987.

Sutherland, J.K., "Environmental Radiation Monitoring Data for Point Lepreau Generating Station," Report HP-07000-85-1, NBEPC, February 1985.

USNRC, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Regulatory Guide 1.109, October 1977.
Veluri, V.R. Boone, F.W and Palms, J.M., "The Environmental Impact of C-14 Released by a Nuclear Fuel-Reprocessing Plant," Nuclear Safety, Vol. 17, No. 5, September-October 1976.

Veluri, V.R., Boone, F.W. and Palms, J.M., "The Environmental Impact of C-14 Released by a Nuclear Fuel-Reprocessing Plant," Nuclear Safety, Vol. 17, No. 5, September-October 1976.

Vikis, A.C., "The Photochemical Method for Radioiodine Abatement," AECL-7819, November 1984.

Villforth, J.C., "Basic Concepts and Principles of Assessment - A Review of the Advisory Committee Report on the Biological Effects of Ionizing Radiation," IAEA-SM-184/100, 1974.

Washburn & Gillis Associates Ltd, "Lepreau 2 - Environmental Impact Statement," Maritime Nuclear, May 1984.

Washburn & Gillis Associates Ltd, "Lepreau 2 - Environmental Impact Statement Supplemental Information," Maritime Nuclear, September 1984.

Williamson, A.S., "Compactable Reactor Waste Characterization," Report No. 85-58-K, March 27, 1985.

Wong, K.Y., "Basis for Derived Limits for the Release of Radionuclides in Gaseous and Liquid Effluents from Ontario Hydro's Nuclear Stations," H.P.D.-73-6, September 1973.

Wuschke, D.M., Branard, J.W., O'Connor, P.A. and Johnson, J.R., "Predictions of Local, Regional and Global Radiation Doses from Iodine-129 for Four Different Disposal Methods and an All-Nuclear Future," AECL-8438.

Young, T.E. and Magleby, E.H., "Technical Evaluation of Rets-Required Reports for Zion Nuclear Power Station, Units 1 and 2 for 1983," EGG-PBS-7002, August 7, 1985.

APPENDIX A

COSTS OF DETRITIATION PLANTS AND SHIPMENT OF HEAVY WATER

This Appendix gives details of the cost estimates for the detritiation technologies discussed in Section 2.

At Darlington, detritiation will be done using the Darlington Tritium Removal Facility, which is being commissioned in 1987.

At Point Lepreau, for Point Lepreau II, this study chose the option of building a dedicated detritiation plant solely for detritiation of heavy water for Point Lepreau II. (Note that the terms of reference for this study did not include consideration of detritiation of the existing Point Lepreau reactor, either singly or in combination with Point Lepreau II.)

A.1 General Cost Factors

The Darlington TRF was designed by Sulzer Canada Inc. The plant has the capacity for a heavy water feed rate of 370 Kg/h with the tritium burden of the heavy water being reduced by a factor of 12.

The CRNL plant is a prototype designed for a heavy water feed rate of 20 Kg/h and a tritium reduction factor of 6.

The cost factors for the Darlington and CRNL tritium removal facilities have been assembled from discussions with staff at Sulzer Canada Inc., Ontario Hydro and CRNL. The capital cost is, with only small variance, a linear function of the required heavy water feed throughput rate.

Figure A.1 shows the capital cost versus heavy water feed rates of 20-400 Kg/hr, which covers the range of interest in this study.

The average tritium generation rate for a CANDU 600 MW(e) reactor is about 50,000 TBq per full power year. From this generation rate the feed rates to a tritium removal facility were calculated so as to achieve steady state moderator concentrations for the range 12-370 GBq/Kg. The associated plant capital costs were then obtained from Figure 1 and plotted in Figure 2.

Figure 2 shows that the capital cost for a tritium removal facility increases rapidly for target steady state moderator concentrations below 100 GBq/Kg.

The annual cost of a detritiation facility was judged to be 30 percent of the capital cost. This annual cost includes debt amortization payments and the annual operating costs.

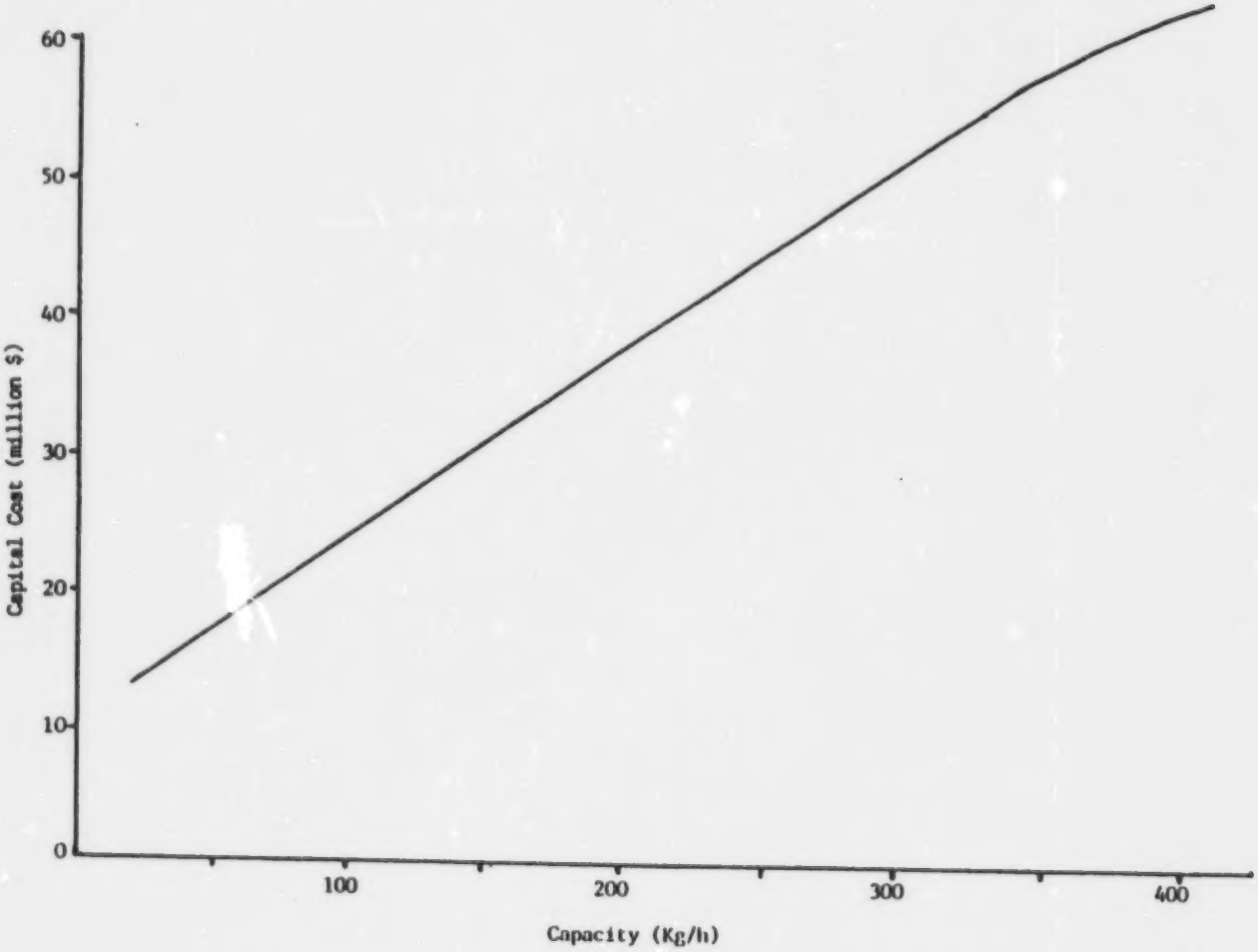


Figure A.1 - Estimated Capital Cost of Tritium Reduction Facilities

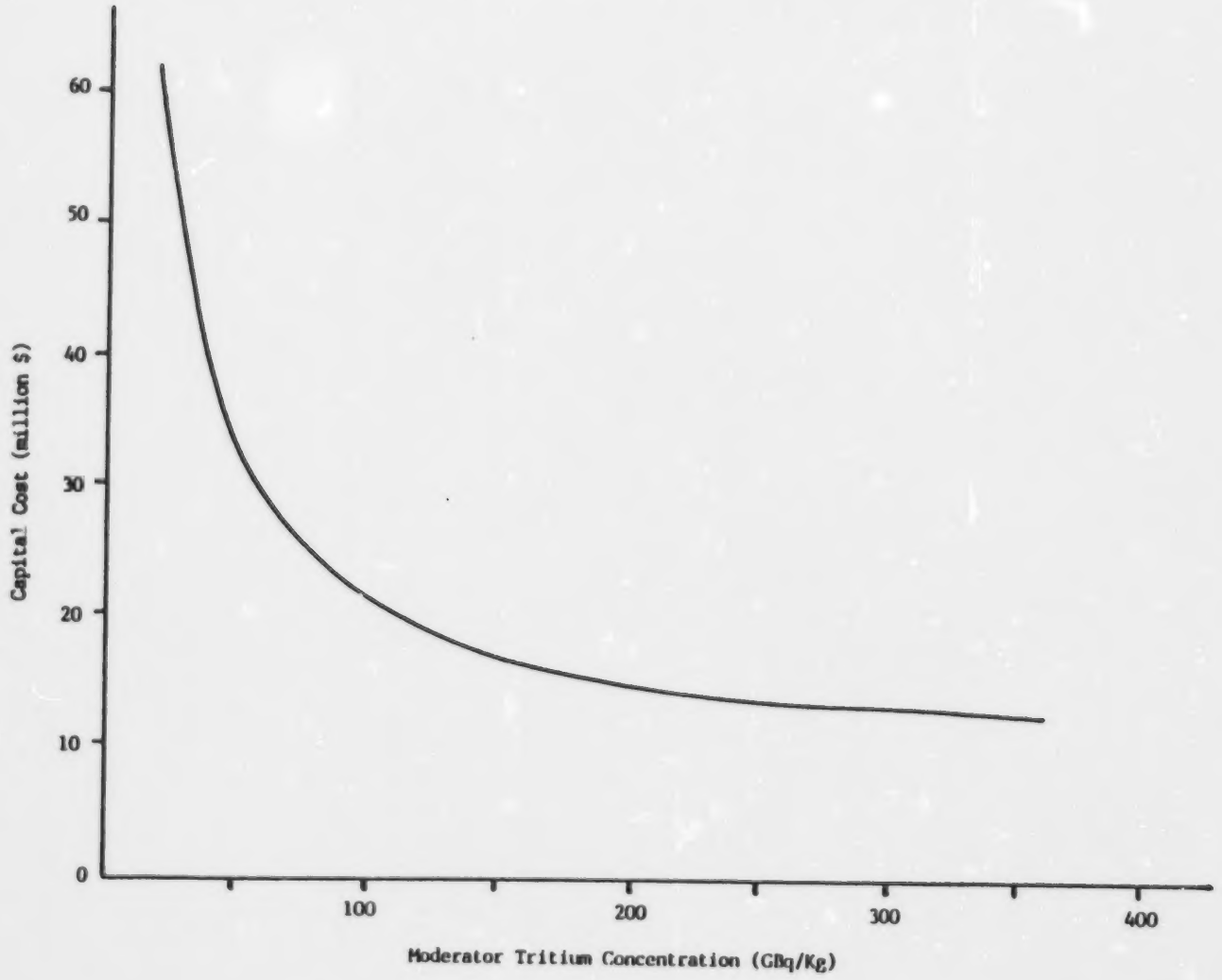


Figure A.2 - Effect of Moderator Tritium Concentration on Capital Cost (600 MW(e) CANDU NGS)

A.2 Cost for Darlington NGS

If the Darlington TRF is used for all Ontario Hydro reactors, the moderator concentration in all units will be reduced to 370 GBq/Kg in about 5 years. Darlington will be allowed to build up to this level in about 3 years before beginning feed to the TRF. At this stage, Darlington will use 20 percent of the capacity of the TRF.

For an expected heavy water feed rate of 370 Kg/h, the capital cost of the TRF is $60 M (Figure A.1). The annual operating cost is expected to be 30 percent of the capital cost, or $18 M. Prorating for the Darlington NGS share of 20 percent gives an annual cost of $3.6 M.

A.3 Cost for Point Lepreau II NGS

Three options were considered for detritiation technology for the Point Lepreau II NGS; namely,

(1) Construct a dedicated tritium removal facility on site.

(2) Ship the heavy water to CRNL for detritiation.

(3) Ship the heavy water to Darlington for detritiation.

A.3.1 Cost of a Dedicated Plant

The capital cost for a dedicated plant at the Point Lepreau site can be obtained from Figure A.2. This figure was based on the tritium generation rate for a 600 MW(e) plant. Assuming a target moderator tritium concentration of 370 GBq/Kg, the capital cost would be $12 M.

The annual cost of the plant is expected to be 30 percent of the capital cost, or $3.6 M.

A.3.2 Cost of Shipping to Darlington or CRNL

Shipping costs would be very similar whether heavy water from Point Lepreau II was shipped to Darlington or to CRNL (Chalk River, Ontario) since both locations are approximately the same distance from Point Lepreau.

The costs for shipment of the heavy water for detritiation are estimated below. The estimates are based on a tritium generation rate of 5600 TBq/a and a target of 370 GBq/Kg for tritium in the moderator. This requires shipment of 150 Mg/a.

A) Capital Cost Factors

Purchase of two Type B shipping containers each of 5 Mg capacity	$ 500,000
Purchase of 10 Mg additional heavy water at $300/Kg	$ 3,000,000
Total Capital Expenditure	$ 3,500,000

B) Incremental Cost Factors

Truck rental	$ 4,000/trip
Detritiation processing charge	$ 54/TBq

C) Estimated Annual Cost

Container debt recovery: 20 per cent of capital cost	$ 100,000
Debt recovery for additional heavy water inventory: 10 per cent of capital cost	$ 300,000
Detritiation charges	$ 3,000,000
Transportation charges	$ 60,000
Total Annual Cost	$ 3,460,000

SITE DATA FOR THE LOCAL PATHWAY MODELS

The local dose calculations are based on the CSA N288.1 document as described in Section 5. The AECB provided the following documents with site specific data for the pathway models:

1) The Basis for the Derived Limits for the Emission of Radionuclides in Airborne and Liquid Effluents from Ontario Hydro's Nuclear Facilities, D.J. Gorman, Ontario Hydro.

2) The Derived Emission Limits of Radionuclides in the Airborne and Liquid Effluents from Darlington Nuclear Generating Station A, Ontario Hydro.

3) Point Lepreau Generating Station Derived Emission Limits for Radionuclides in Gaseous and Liquid Effluents. NB Electric Power Commission.

4) Site Characteristics - Pt. Lepreau, Section 2 of Pt. Lepreau Safety Report.

5) Factors Affecting a Release, Section 2 of the Darlington Safety Report.

6) Radioactive Release Data from Canadian Nuclear Generating Station 1972 to 1985. AECB INFO Report 0210, Sept. 1986.

The following sections summarize site specific environmental data and assumptions made for the transfer parameters. Default values for the model are taken from Gorman's report unless otherwise stated.

A FORTRAN-77 program CLDOSL was written to calculate the individual and collective doses for the various radionuclides. Appendix D contains a listing of the program and its data files. In particular, the transfer parameters for each radionuclide at each site are given as data file listings in Tables D.2 and D.3. Note that the transfer parameter P01 (atmospheric dilution) is given in Tables B.5 and B.6 for the two sites.

B.1. Site Specific Population Distributions

B.1.1 Point Lepreau II NGS

Pt. Lepreau II will be built on the site of Pt. Lepreau I. The site is located approximately 40 km southwest of Saint John, New Brunswick, on the Bay of Fundy (Figure 3).

Environmental data and site characteristics were taken from the Pt. Lepreau Safety Report and the DEL Report. The following assumptions are made for the local dose calculations:

1) The region of 60 Km radius about the plant is divided into 9 concentric circles and subdivided radially into 8 sectors forming 72 compartments.

2) The 1981 census data for each compartment is weighted by a factor of 1.072 to allow for population growth to December 31, 1987. Table B.1 gives the adjusted population distribution.

3) Infants under two years of age are assumed to be 3% of the population. The Dose Conversion factors are for an infant one year of age.

4) The dose calculation in any compartment assumes all the population is located at the centroid of the compartment.

5) Wind rose data was taken from the Pt. Lepreau Safety Report and is given in Table B.2.

6) There is no transfer between the water and atmospheric compartments, i.e. P12 = 0.

7) Tritium is released as HTO in the atmosphere as vapour and as a liquid effluent.

B.1.2 Darlington NGS

Darlington NGS site is located on the north shore of Lake Ontario (Figure 4). Environmental and site characteristics are obtained from the Darlington Safety Report and DEL report.

The same assumptions are made for the Darlington site as for the Pt. Lepreau II site (see B.1.1) except as follows:

1) The region 50 Km radius around the site is divided into 6 concentric circles and subdivided radially into 8 sectors to form 48 compartments.

2) The population data for the area is the population projected to 1988. Table B.3 gives the projected population distribution.

3) The wind rose data was taken from the Darlington Safety Report and adjusted to 8 sectors from 16. The adjusted data are given in Table B.4.

Table B.1 Distribution of Population around Point Lepreau II NGS

Sector	Radius (Km)								
	2.5	7.5	12.5	17.5	22.5	27.5	35	45	55
N	91	414	252	69	0	0	1735	1178	430
NE	166	96	228	360	0	3173	82381	9581	12203
E	0	0	0	0	0	0	90	198	596
SE	0	0	0	0	0	0	0	0	0
S	0	0	0	0	0	0	403	270	274
SW	0	0	0	0	0	0	1635	1630	2549
W	0	75	1258	220	1878	2392	1580	4278	1694
NW	169	278	115	37	81	340	186	379	386

Estimated total population to 60 Km equals 135,348.

Table B.2 Point Lepreau II Wind Rose Weighting Factors

Direction	% Wind Direction
N	10
NE	9.2
E	11.2
SE	4.2
S	15.0
SW	10.0
W	20.8
NW	16.6

Table B.3 Distribution of Population Around Darlington NGS

Sector	Radius (Km)					
	2.5	7.5	15	25	35	45
N	1,000	15,000	20,000	10,000	7,000	15,000
NE	8,000	10,000	10,000	10,000	6,000	20,000
E	1,000	5,000	5,000	5,000	10,000	10,000
SE	0	0	0	0	0	0
S	0	0	0	0	0	0
SW	0	0	0	0	0	0
W	1,000	15,000	7,000	40,000	120,000	400,000
NW	1,000	1,000	30,000	20,000	40,000	40,000

Estimated total population to 50 Km equals 955,000.

Table B.4 Darlington Wind Rose Weighting Factors

Direction	% Wind Direction
N	13
NE	15
E	10.5
SE	3.5
S	4.0
SW	12.5
W	24.0
NW	14.0

B.2 Dose from Airborne Pathways

B.2.1 Pt. Lepreau II NGS

The following assumptions were made for the atmospheric dispersion pathways:

1) CSA standard N288.1 was used to obtain the dilution factors P01 for a 50 m stack. Table B.5 gives the dilution factors as a function of radius.

2) The dose due to skyshine is calculated for the noble gases (P19(e)).

3) All agricultural products are from a point 70 Km NE of Point Lepreau (near the town of Sussex). Fifty percent of the food consumed in the region is from this source. The remaining 50% is uncontaminated. Home gardens are not included as a food source.

4) The average agricultural food consumption is taken from Gorman's report. No grain is grown locally. Thus, there is no contribution to dose from grain or cereal products.

5) The populace resides out of doors 20% of the time.

6) P(i)19, P13, P14, P15, P34, P45, P39, P49, P59 are given default values.

7) The external exposure transfer parameter (P(e)19) is assumed to have the default value. The value for an infant is 1.5 times the value for an adult.

8) No particulate emissions are reported for Pt. Lepreau I. Thus, no estimate is made for a dose from particulate emissions.

B.2.2 Darlington NGS

The following assumptions were made for the atmospheric dispersion pathways:

1) CSA standard N288.1 was used to obtain the dilution factors P01 for a 50 m stack. Table B.6 gives the dilution factors as a function of radius.

2) Agricultural products are produced 15 Km away in the NW sector. It is assumed that 50% of the agricultural consumption is from local produce.

Table B.5 Atmospheric Dilution Factors for Point Lepreau II NGS

Radius	Dilution Parameter (PO1)
2.5	1.2 E-7
7.5	3.5 E-8
12.5	1.8 E-8
17.5	1.2 E-8
22.5	8.5 E-9
27.5	6.4 E-9
35.0	4.6 E-9
45.0	3.3 E-9
55.0	2.5 E-9

Table B.6 Atmospheric Dilution Factors for Darlington NGS

Radius	Dilution Parameter (PO1)
2.5	1.2 E-7
7.5	3.5 E-8
15.0	1.45 E-8
25.0	7.3 E-9
35.0	4.6 E-9
45.0	3.3 E-9

3) Particulate emissions are assumed to be Sr-89, Sr-90 or Co-60. The dose was calculated with the total emission figure being attributed to the most restrictive radionuclide, Co-60.

4) Transfer parameters are those given in the Darlington DEL report.

B.3 Dose from Waterborne Pathways

B.3.1 Point Lepreau NGS

The radionuclides chosen for the liquid effluent pathway are from the Point Lepreau DEL report. The source term obtained from the AECB report INFO-0210 provides data only on the gross beta-gamma activity released from the plant. A dose calculation for each radionuclide (including H-3) was done with the total emission term set equal to the activity of each radionuclide. The most restrictive nuclide was taken to be the nuclide which gave the highest collective dose. For Point Lepreau II, this is Zn-65. Thus, all activity released via the liquid effluent pathway is assumed to be Zn-65.

The following assumptions are also incorporated into the model:

1) There is no transfer between atmospheric and water compartments (P12 = 0).

2) There is no effect from water on crops or animals (P23 = P24 = P25 = 0).

3) There is minimal swimming or drinking of water in the Bay of Fundy (P(i)29 = P(e)29 = 0).

4) Exposure from sea sediments is considered negligible (P28 = 0).

The major water pathway to man is from the seafood caught and consumed within the local region. The following assumptions are made:

1) The Bay of Fundy dilutes the source term by a factor of 1000.

2) The distribution of radionuclides released to the Bay of Fundy is considered to be homogeneous.

3) The average consumption of seafood is set at 16 Kg/year for adults divided as follows:

   12 Kg/year fish
   4 Kg/year crustaceans and mollusks
   0.18 Kg/year of dulse.

Children consume 10% of these values. Only fish locally caught are consumed.

4) Activity in the liquid stream is diluted in the hold up tanks and the condenser cooling water outfall. These dilutions are incorporated in the source term.

5) The decay factor is set conservatively to 1 for all the radionuclides analyzed.

6) The transfer parameters from liquid to aquatic animals is set to the default value.

7) The transfer from liquid to seaplants (dulse) is taken from the Point Lepreau DEL report.

8) Transfer between aquatic animals, plants and sediments is considered to be negligible P87 = P76 = P86 = 0.

B.3.2 Darlington NGS

The following assumptions are made for calculating exposure to the populace due to releases of liquid effluent from the Darlington NGS:

1) The communities of Ajax, Oshawa, Bowmanville, Newcastle and Whitby obtain their drinking water from the lake. Default transfer parameters are used and these areas are assumed to obtain all their drinking water from their sectors. No credit is given for filtration or other processes which may occur at a water treatment facility. The sources of drinking water are taken to be:

   a) 4.5 Km east of Darlington for Bowmanville and Newcastle.
   b) 4.5 Km west of Darlington for Oshawa, Whitby and Ajax.

2) The Darlington DEL report uses:

   a) a lake current of 0.11 m/s
   b) a decay term for each radionuclide
   c) the factor for plant recirculation equals 1.15
   d) the lake current is in the direction of the drinking water site at the lake current velocity.

3) Two hundred thousand people visit Darlington Provincial Park each year. The qualitative factor of 0.2 is multiplied by the default transfer parameter for the immersion in water (Pe(29)) and the default transfer parameter for the exposure to contaminated sediment (P89).

4) No aquatic plants from Lake Ontario are consumed (P27 = P76 = P69 = P87 = 0).

5) In 1979, approximately 2000 Kg of fish was caught in Lake Ontario. This yields 0.002 Kg/year per person in the Darlington region. This is negligible compared to the 5.5 Kg/year average Canadian consumption.

APPENDIX C

CALCULATION OF GLOBAL DOSE REDUCTIONS

The NEA model [Ref. 3] was used to calculate the global collective dose equivalent commitment for the radionuclides H-3, C-14, Kr-85 and I-129.

The model is independent of the mode and site of emission of the radionuclides analyzed. The world population is set equal to 10 billion people. The global dose is calculated assuming uniform dispersion of the emitted radionuclide on a global scale. The time of integration is for a 10,000 year period.

In Table 10 of Reference 3, the incomplete collective dose equivalent commitment is tabulated for each radionuclide and it is given per unit of activity emitted. The values are as follows:

H-3 : 5.8 E-4 Person-Sv/TBq

C-14 : 79 "

Kr-85 : 2.9 E-4 "

I-129 : 8.1 "

The above quantities represent the collective dose that would be saved if the unit emission were withheld from the biosphere for 10,000 years.

With the above factors the source terms from Table 9, the dose reductions are readily calculated for the technologies discussed in Sections 2 and 4.

Example

For the Point Lepreau II reactor the tritium releases to air and water are 49.3 and 194 TBq/a, respectively. Over the 50 year life of the plant 243 x 50 TBq will be added to the global biosphere. Thus, the incomplete collective dose equivalent commitment will be 7.05 Person-Sv.

Detritiation technology at Point Lepreau II (Section 2) is judged to decrease emissions by a factor of 3. Therefore the saving in collective dose commitment is 4.7 Person-Sv.

APPENDIX D

DATA FROM LOCAL DOSE CALCULATIONS

This appendix contains relevant data from the local dose calculations for the Darlington NGS and Point Lepreau II NGS. It consists of the input and output data sets from the computer program CLDOSL. The program was used to calculate the individual and collective doses as described in Section 5 and Appendix B. The data sets are given for the following radionuclide emissions:

C-14	Kr-85
Co-60	Sr-89
Fe-59	Sr-90
H-3	Xe-133
I-129	Zn-65
I-131	Zr/Nb-95

D.1 Transfer Parameters for Pathway Model

The transfer parameters for the environmental pathway model are defined in Table D.1 along with the units.

Tables D.2 and D.3 give the transfer parameters for each nuclide for the Darlington and Point Lepreau sites, respectively.

D.2 Spatial Distribution of Individual and Collective Doses

Tables D.4 and D.5 give the spatial distributions of the individual and collective doses for the Darlington and Point Lepreau sites, respectively. The grids of compartments are as described in Appendix B.

D.3 Program Listing for CLDOSL

The program CLDOSL was used for the local pathway calculations. It is written in FORTRAN 77. A listing is given in Table D.6. Sample input data files are given in Table D.7.

Table D.1 - Definition of Transfer Parameters

Transfer Parameter	Compartments			Units
P_{01}	Source	→	Atmosphere	$s \cdot m^{-3}$
P_{12}	Atmosphere	→	Surface Water	$m^3 \cdot L^{-1}$
P_{13}	Atmosphere	→	Vegetated Soil	m
P_{14}	Atmosphere	→	Forage and Crops	$m^3 \cdot kg^{-1}$
P_{15}	Atmosphere	→	Animal Produce	$m^3 \cdot kg^{-1}$
$P(i)_{19}$	Atmosphere	→	Dose (inhalation)	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot m^3$
$P(e)_{19}$	Atmosphere	→	Dose (immersion)	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot m^3$
P_{02}	Source	→	Surface Water	$s \cdot L^{-1}$
P_{23}	Surface Water	→	Vegetated Soil	$L \cdot m^{-2}$
P_{24}	Surface Water	→	Forage and Crops	$L \cdot kg^{-1}$
P_{25}	Surface Water	→	Animal Produce	$L \cdot kg^{-1}$
P_{26}	Surface Water	→	Aquatic Animals	$L \cdot kg^{-1}$
P_{27}	Surface Water	→	Aquatic Plants	$L \cdot kg^{-1}$
P_{28}	Surface Water	→	Sediment	$L \cdot kg^{-1}$
$P(i)_{29}$	Surface Water	→	Dose (ingestion)	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot L$
$P(e)_{29}$	Surface Water	→	Dose (immersion)	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot L$
P_{34}	Vegetated Soil	→	Forage and Crops	$m^2 \cdot kg^{-1}$
P_{39}	Vegetated Soil	→	Dose	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot m^2$
P_{45}	Forage and Crops	→	Animal Produce	$kg \cdot kg^{-1}$
P_{49}	Forage and Crops	→	Dose	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot kg$
P_{59}	Animal Produce	→	Dose	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot kg$
P_{69}	Aquatic Animals	→	Dose	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot kg$
P_{79}	Aquatic Plants	→	Dose	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot kg$
P_{89}	Sediment	→	Dose	$Sv \cdot a^{-1} \cdot Bq^{-1} \cdot kg$

Table D.2 - Transfer Parameters for the Darlington Site

Notes:

1. The first line of each file listing identifies the radionuclide.
2. The abbreviations 'ad' and 'inf' are for adult and infant, respectively.
3. Kr-85 and Xe-133 are combined as 'noble gases'.
4. The second line of the file listing gives the emissions to atmosphere and water. The atmospheric term is a source term and the water term is compartment 2.

```
** file C-14.dar1.loc ** Pmn parameters for program cldosl - C-14
*
 1.20E+5    0.02    :: emission in Air (Bq/sec), Water (Bq/L)
*
  4.3E-8   P(i)19_ad  ::  Transfer parameters for air source
  2.1E-8   P(i)19_inf
       0   P(e)19
       0   P13
 2.75E+3   P14_forage
 3.75E+2   P14_crops
     4.2   P15_milk
     5.1   P15_beef
     5.4   P15_pork
     5.0   P15_eggs
     8.0   P15_chicken
       0   P34_forage
       0   P34_crops
  1.5E-1   P45_milk
  6.4E-1   P45_beef
  5.4E-1   P45_pork
  3.1E-1   P45_eggs
  4.2E-1   P45_chicken
       0   P39
 5.30E-8   P49_adult
 6.64E-8   P49_inf
 4.53E-8   P59_milk_ad
 1.74E-7   P59_milk_inf
 9.22E-9   P59_beef_ad
 9.50E-9   P59_beef_inf
 9.22E-9   P59_pork_ad
 9.50E-9   P59_pork_inf
 1.82E-9   P59_eggs_ad
 3.97E-9   P59_eggs_inf
 4.16E-9   P59_chkn_ad
 7.92E-9   P59_chkn_inf
     0.0   P26_frfsh     :: Water source
     0.0   P26_ocnfsh
     0.0   P26_crust,mollusc
       0   P27
       0   P28
       0   P69_frfsh
       0   P69_ocnfsh
       0   P69_crst,mllsc
       0   P79
       0   P89
3.83E-12   RD(02) (lambda_r)
 3.60E-7   P(i)29_adult
 4.80E-7   P(i)29_inf
       0   P(e)29
       0
       0
       0
       0
*
```

```
** file nbgs.darl.loc ** Pmn parameters for program cldosl - noble gases
*
 2.54E+7       0    :: emission in Air (Bq-Mev/sec), Water (Bq/L)
*
       0   P(i)19_ad  ::  Transfer parameters for air source
       0   P(i)19_inf
 1.56E-6   P(e)19     ::  "Shine" only
       0   P13
       0   P14_forage
       0   P14_crops
       0   P15_milk
       0   P15_beef
       0   P15_pork
       0   P15_eggs
       0   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
 8.8E-8    P59_chkn_ad
4.35E-7    P59_chkn_inf
    50.0   P26_frfsh     :: Water source  (not used)
    20.0   P26_ocnfsh
    50.0   P26_crust,mollusc
 7.8E-2    P27
       0   P28
       0   P69_frfsh
1.32E-7    P69_ocnfsh
 4.4E-8    P69_crst,mllsc
 8.8E-9    P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0
       0
       0
       0
*
```

```
** file H3vp.dar1.loc ** Pmn parameters for program cldos1 - tritium vapour
*
  6.3E+7  2.3E+2    :: emission in Air (Bq/sec), Water (Bq/L)
*
  3.3E-7      ::  Transfer parameters for air source
  1.6E-7
       0
       0
    50.0
    50.0
     3.9
     1.4
     2.2
     3.5
     6.7
       0
       0
     .14
     .18
     .22
     .22
     .35
       0
 2.03E-9
 2.44E-9
 1.74E-9
 6.38E-9
3.55E-10
3.48E-10
3.55E-10
3.48E-10
 1.4E-10
1.45E-10
 1.6E-10
 2.9E-10
       0         :: Water source
       0
       0
       0
       0
       0
       0
       0
       0
       0
 1.78E-9
  1.4E-8
  1.7E-8
 8.4E-12
       0
       0
       0
       0
*
```

```
** file I131.dar1.loc ** Pmn parameters for program cldos1 - I131
*
     6.3     0.02     :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5    P(i)19_ad  ::  Transfer parameters for air source
  1.2E-4    P(i)19_inf
 4.76E-7    P(e)19
  1.0E+4    P13
 2.23E+4    P14_forage
 4.55E+3    P14_crops
     2.8    P15_milk
  2.9E-1    P15_beef
  9.9E-2    P15_pork
     4.5    P15_eggs
  3.8E-1    P15_chicken
  4.0E-3    P34_forage
  3.0E-4    P34_crops
  5.0E-2    P45_milk
  1.8E-2    P45_beef
  5.0E-3    P45_pork
  1.4E-1    P45_eggs
  1.0E-2    P45_chicken
 3.92E-9    P39
 1.12E-6    P49_adult
 3.65E-6    P49_inf
 9.57E-7    P59_milk_ad
 9.57E-6    P59_milk_inf
 1.95E-7    P59_beef_ad
 5.22E-7    P59_beef_inf
 1.95E-7    P59_pork_ad
 5.22E-7    P59_pork_inf
 3.85E-8    P59_eggs_ad
 2.18E-7    P59_eggs_inf
  8.8E-8    P59_chkn_ad
 4.35E-7    P59_chkn_inf
       0    P26_frfsh      :: Water source
       0    P26_ocnfsh
       0    P26_crust,mollusc
       0    P27
   2.0E2    P28
       0    P69_frfsh
       0    P69_ocnfsh
       0    P69_crst,mllsc
       0    P79
2.62E-10    P89
 1.00E-6    RD(02) (lambda_r)
 7.70E-6    P(i)29_adult
 2.60E-5    P(i)29_inf
 2.26E-9    P(e)29
       0    P69,79_inf
       0
       0
       0
*
```

```
** file I129.darl.loc ** Pmn parameters for program cldosl - I129
*
  3.2E-8       0     !! emission in Air (Bq/sec), Water (Bq/L)
*
 6.47E-4   P(i)19_ad  !!  Transfer parameters for air source
 2.52E-4   P(i)19_inf
 1.04E-8   P(e)19
 4.55E+7   P13
 4.82E+4   P14_forage
 1.18E+4   P14_crops
      2.8  P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
      4.5  P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  1.0E-1   P45_milk
  3.6E-2   P45_beef
  1.0E-2   P45_pork
  2.8E-1   P45_eggs
  2.0E-2   P45_chicken
2.14E-10   P39
 7.94E-6   P49_adult
 3.65E-6   P49_inf
 6.79E-6   P59_milk_ad
 1.98E-5   P59_milk_inf
 1.38E-6   P59_beef_ad
 1.08E-6   P59_beef_inf
 1.38E-6   P59_pork_ad
 1.08E-6   P59_pork_inf
 2.73E-7   P59_eggs_ad
 4.51E-7   P59_eggs_inf
 6.24E-7   P59_chkn_ad
 9.00E-7   P59_chkn_inf
     50.0  P26_frfsh     !! Water source (not used)
     20.0  P26_ocnfsh
     50.0  P26_crust,mollusc
  7.8E-2   P27
        0  P28
        0  P69_frfsh
 1.32E-7   P69_ocnfsh
  4.4E-8   P69_crst,mllsc
  8.8E-9   P79
        0  P89
      1.0  RD(02)
        0  P(i)29_adult
        0  P(i)29_inf
        0  P(e)29
        0
        0
        0
        0
*
```

```
** file Co60.dar1.loc ** Pmn parameters for program cldos1 - Co60
*
     2.2     0.02     !! emission in Air (Bq/sec), Water (Bq/L)
*
  5.8E-4    P(i)19_ad  !!  Transfer parameters for air source
  2.5E-4    P(i)19_inf
 3.22E-6    P(e)19
 6.84E+5    P13
 1.44E+4    P14_forage
 3.53E+3    P14_crops
  4.8E-1    P15_milk
  4.7E-1    P15_beef
  3.0E+0    P15_pork
       0    P15_eggs
       0    P15_chicken
  4.0E-4    P34_forage
  8.0E-5    P34_crops
  2.9E-2    P45_milk
  1.0E-1    P45_beef
  5.1E-1    P45_pork
       0    P45_eggs
       0    P45_chicken
  2.2E-8    P39
 1.73E-6    P49_adult
 7.56E-7    P49_inf
 1.44E-6    P59_milk_ad
 3.96E-6    P59_milk_inf
 3.02E-7    P59_beef_ad
 2.16E-7    P59_beef_inf
 3.02E-7    P59_pork_ad
 2.16E-7    P59_pork_inf
 1.19E-7    P59_eggs_ad
 9.00E-8    P59_eggs_inf
 13.6E-8    P59_chkn_ad
 18.0E-8    P59_chkn_inf
       0    P26_frfsh      !! Water source
       0    P26_ocnfsh
       0    P26_crust,mollusc
       0    P27
    3.0E4   P28
       0    P69_frfsh
       0    P69_ocnfsh
       0    P69_crst,mllsc
       0    P79
 .924E-9    P89
 4.23E-9    RD(02) (lambda_r)
  1.2E-5    P(i)29_adult
  1.1E-5    P(i)29_inf
 1.52E-9    P(e)29
       0    P69,79_inf
       0
       0
       0
*
```

```
** file Zn65.dar1.loc ** Pmn parameters for program cldos1 - Zn65
*
       0    0.02    :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  ::  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
 8.8E-8    P59_chkn_ad
4.35E-7    P59_chkn_inf
       0   P26_frfsh      :: Water source
       0   P26_ocnfsh
       0   P26crst,mollusc
       0   P27
  1.0E+3   P28
       0   P69_frfsh
       0   P69_ocnfsh
       0   P69_crst,mllsc
       0   P79
.356E-9    P89
9.0E-11    RD(02)
 2.8E-6    P(i)29_adult
 3.0E-6    P(i)29_inf
.356E-8    P(e)29
       0
       0
       0
       0
*
```

```
** file Zr95.darl.loc ** Pmn parameters for program cldosl - Zr_Nb_95
*
       0     0.02     :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5    P(i)19_ad  ::  Transfer parameters for air source  (not used)
  1.2E-4    P(i)19_inf
 4.76E-7    P(e)19
  1.0E+4    P13
 2.23E+4    P14_forage
 4.55E+3    P14_crops
     2.8    P15_milk
  2.9E-1    P15_beef
  9.9E-2    P15_pork
     4.5    P15_eggs
  3.8E-1    P15_chicken
  4.0E-3    P34_forage
  3.0E-4    P34_crops
  5.0E-2    P45_milk
  1.8E-2    P45_beef
  5.0E-3    P45_pork
  1.4E-1    P45_eggs
  1.0E-2    P45_chicken
3.92E-9     P39
1.12E-6     P49_adult
3.65E-6     P49_inf
9.57E-7     P59_milk_ad
9.57E-6     P59_milk_inf
1.95E-7     P59_beef_ad
5.22E-7     P59_beef_inf
1.95E-7     P59_pork_ad
5.22E-7     P59_pork_inf
3.85E-8     P59_eggs_ad
2.18E-7     P59_eggs_inf
 8.8E-8     P59_chkn_ad
4.35E-7     P59_chkn_inf
       0    P26_frfsh      :: Water source
       0    P26_ocnfsh
       0    P26crst,mollusc
       0    P27
  1.0E+4    P28
       0    P69_frfsh
       0    P69_ocnfsh
       0    P69_crst,mllsc
       0    P79
1.56E-9     P89
1.25E-7     RD(82) (lambda_r)
 6.2E-7     P(i)29_adult
 3.6E-7     P(i)29_inf
1.44E-8     P(e)29
       0
       0
       0
       0
*
```

```
** file Sr90.darl.loc ** Pmn parameters for program cldosl - Sr90
*
     2.2     0.02     :: emission in Air (Bq/sec), Water (Bq/L)
*
  3.5E-3    P(i)19_ad   ::  Transfer parameters for air source
  2.7E-3    P(i)19_inf
       0    P(e)19
 3.05E+6    P13
 1.44E+4    P14_forage
 3.54E+3    P14_crops
  5.9E-1    P15_milk
  9.6E-2    P15_beef
  1.7E+0    P15_pork
     4.5    P15_eggs
  7.0E-1    P15_chicken
  8.0E-3    P34_forage
  3.0E-4    P34_crops
  1.4E-2    P45_milk
  8.1E-2    P45_beef
  1.2E-1    P45_pork
  3.0E-2    P45_eggs
  3.5E-3    P45_chicken
       0    P39
 3.45E-6    P49_adult
 1.01E-5    P49_inf
 2.88E-6    P59_milk_ad
 2.63E-5    P59_milk_inf
 6.03E-7    P59_beef_ad
 1.44E-6    P59_beef_inf
 6.03E-7    P59_pork_ad
 1.44E-6    P59_pork_inf
 2.38E-7    P59_eggs_ad
 5.99E-7    P59_eggs_inf
 2.72E-7    P59_chkn_ad
 1.20E-6    P59_chkn_inf
       0    P26_frfsh      :: Water source
       0    P26_ocnfsh
       0    P26_crust,mollusc
       0    P27
    3.0E4   P28
       0    P69_frfsh
       0    P69_ocnfsh
       0    P69_crst,mllsc
       0    P79
       0    P89
7.58E-10    RD(02) (lambda_r)
  2.4E-5    P(i)29_adult
  7.2E-5    P(i)29_inf
       0    P(e)29
       0    P69,79_inf
       0
       0
       0
*
```

```
** file Sr89.dar1.loc ** Pmn parameters for program cldos1 - Sr89
*
     2.2     0.02     !! emission in Air (Bq/sec), Water (Bq/L)
*
  1.1E-4    P(i)19_ad  !!  Transfer parameters for air source
  8.5E-5    P(i)19_inf
1.84E-10    P(e)19
 1.89E+4    P13
 1.24E+4    P14_forage
 2.86E+3    P14_crops
  5.9E-1    P15_milk
  9.6E-2    P15_beef
  1.7E+0    P15_pork
     4.5    P15_eggs
  7.0E-1    P15_chicken
  8.0E-3    P34_forage
  3.0E-4    P34_crops
  1.4E-2    P45_milk
  8.1E-2    P45_beef
  1.2E-1    P45_pork
  3.0E-2    P45_eggs
  3.5E-3    P45_chicken
       0    P39
 2.54E-7    P49_adult
 7.56E-7    P49_inf
 2.12E-7    P59_milk_ad
 1.98E-6    P59_milk_inf
 4.44E-8    P59_beef_ad
 1.08E-7    P59_beef_inf
 4.44E-8    P59_pork_ad
 1.08E-7    P59_pork_inf
 1.75E-8    P59_eggs_ad
 4.50E-8    P59_eggs_inf
  2.0E-8    P59_chkn_ad
 9.00E-8    P59_chkn_inf
       0    P26_frfsh      !! Water source
       0    P26_ocnfsh
       0    P26_crust,mollusc
       0    P27
   3.0E4    P28
       0    P69_frfsh
       0    P69_ocnfsh
       0    P69_crst,mllsc
       0    P79
       0    P89
 1.57E-7    RD(02) (lambda_r)
  1.8E-6    P(i)29_adult
  5.4E-6    P(i)29_inf
 8.0E-13    P(e)29
       0    P69,79_inf
       0
       0
       0
*
```

```
** file Fe59.darl.loc ** Pmn parameters for program cldosl - Fe59
*
      0    0.02    !! emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  !!  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
 8.8E-8    P59_chkn_ad
4.35E-7    P59_chkn_inf
      0    P26_frfsh     !! Water source
      0    P26_ocnfsh
      0    P26crst,mollusc
      0    P27
  1.0E+4   P28
      0    P69_frfsh
      0    P69_ocnfsh
      0    P69_crst,mllsc
      0    P79
.712E-9    P89
1.78E-7    RD(82) (lambda_r)
  1.3E-6   P(i)29_adult
  1.4E-6   P(i)29_inf
.724E-8    P(e)29
      0
      0
      0
      0
*
```

Table D.3 - Transfer Parameters for the Point Lepreau Site

Notes:

1. The first line of each file listing identifies the radionuclide.
2. The abbreviations 'ad' and 'inf' are for adult and infant, respectively
3. Kr-85 and Xe-133 are combined as 'noble gases.'
4. The second line of the file listing gives the emissions to atmosphere and water. The atmospheric term is a source term and the water term is compartment 2.

```
** file C-14.ptlp.loc ** Pmn parameters for program cldosl - C-14
*
 2.15E+4        0     :: emission in Air (Bq/sec), Water (Bq/L)
*
  4.3E-8    P(i)19_ad  ::  Transfer parameters for air source
  2.1E-8    P(i)19_inf
       0    P(e)19
       0    P13
 2.75E+3    P14_forage
 3.75E+2    P14_crops
     4.2    P15_milk
     5.1    P15_beef
     5.4    P15_pork
     5.0    P15_eggs
     8.0    P15_chicken
       0    P34_forage
       0    P34_crops
  1.5E-1    P45_milk
  6.4E-1    P45_beef
  5.4E-1    P45_pork
  3.1E-1    P45_eggs
  4.2E-1    P45_chicken
       0    P39
5.30E-8    P49_adult
6.64E-8    P49_inf
4.53E-8    P59_milk_ad
1.74E-7    P59_milk_inf
9.22E-9    P59_beef_ad
9.50E-9    P59_beef_inf
9.22E-9    P59_pork_ad
9.50E-9    P59_pork_inf
1.82E-9    P59_eggs_ad
3.97E-9    P59_eggs_inf
4.16E-9    P59_chkn_ad
7.92E-9    P59_chkn_inf
    50.0    P26_frfsh      :: Water source (not used)
    20.0    P26_ocnfsh
    50.0    P26_crust,mollusc
 7.8E-2    P27
       0    P28
       0    P69_frfsh
1.32E-7    P69_ocnfsh
 4.4E-8    P69_crst,mllsc
 8.8E-9    P79
       0    P89
     1.0    RD(02)
       0    P(i)29_adult
       0    P(i)29_inf
       0    P(e)29
       0
       0
       0
       0
*
```

```
** file nbgs.ptlp.loc ** Pmn parameters for program cldosl - noble gases
*
 2.54E+4       0    :: emission in Air (Bq-Mev/sec), Water (Bq/L)
*
       0   P(i)19_ad  ::  Transfer parameters for air source
       0   P(i)19_inf
 1.56E-6   P(e)19     ::  "Shine" only
       0   P13
       0   P14_forage
       0   P14_crops
       0   P15_milk
       0   P15_beef
       0   P15_pork
       0   P15_eggs
       0   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
 3.92E-9   P39
 1.12E-6   P49_adult
 3.65E-6   P49_inf
 9.57E-7   P59_milk_ad
 9.57E-6   P59_milk_inf
 1.95E-7   P59_beef_ad
 5.22E-7   P59_beef_inf
 1.95E-7   P59_pork_ad
 5.22E-7   P59_pork_inf
 3.85E-8   P59_eggs_ad
 2.18E-7   P59_eggs_inf
  8.8E-8   P59_chkn_ad
 4.35E-7   P59_chkn_inf
    50.0   P26_frfsh     :: Water source  (not used)
    20.0   P26_ocnfsh
    50.0   P26_crust,mollusc
  7.8E-2   P27
       0   P28
       0   P69_frfsh
 1.32E-7   P69_ocnfsh
  4.4E-8   P69_crst,mllsc
  8.8E-9   P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0
       0
       0
       0
*
```

```
* file H3vp.ptlp.loc ** Pmn parameters for program cldosl - tritium oxide
*
  6.15E6     54.0     :: emission in Air (Bq/sec), Water (Bq/L)
*
  3.3E-7   P(i)19_ad  ::  Transfer parameters for air source
  1.6E-7   P(i)19_inf
        0  P(e)19
        0  P13
     50.0  P14_forage
     50.0  P14_crops
      3.9  P15_milk
      1.4  P15_beef
      2.2  P15_pork
      3.5  P15_eggs
      6.7  P15_chicken
        0  P34_forage
        0  P34_crops
      .14  P45_milk
      .18  P45_beef
      .22  P45_pork
      .22  P45_eggs
      .35  P45_chicken
        0  P39
 2.03E-9   P49_adult
 2.44E-9   P49_inf
 1.74E-9   P59_milk_ad
 4.38E-9   P59_milk_inf
3.55E-10   P59_beef_ad
3.48E-10   P59_beef_inf
3.55E-10   P59_pork_ad
3.48E-10   P59_pork_inf
1.40E-10   P59_eggs_ad
1.45E-10   P59_eggs_inf
 1.6E-10   P59_chkn_ad
 2.9E-10   P59_chkn_inf
        0  P26_frfsh      :: Water source
      1.0  P26_ocnfsh
      1.0  P26_crust,mollusc
     0.99  P27
        0  P28
        0  P69_frfsh
 2.4E-10   P69_ocnfsh
 8.0E-11   P69_crst,mllsc
 1.6E-11   P79
        0  P89
      1.0  RD(02)
  1.4E-8   P(i)29_adult
  1.7E-8   P(i)29_inf
 4.2E-11   P(e)29
        0  P69,79_inf
6.96E-11
2.32E-11
4.64E-12
*
```

```
** file I131.ptlp.loc ** Pmn parameters for program cldosl - I131
*
   0.131   4.6E-3     :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5    P(i)19_ad  ::  Transfer parameters for air source
  1.2E-4    P(i)19_inf
 4.76E-7    P(e)19
  1.0E+4    P13
 2.23E+4    P14_forage
 4.55E+3    P14_crops
     2.8    P15_milk
  2.9E-1    P15_beef
  9.9E-2    P15_pork
     4.5    P15_eggs
  3.8E-1    P15_chicken
  4.0E-3    P34_forage
  3.0E-4    P34_crops
  5.0E-2    P45_milk
  1.8E-2    P45_beef
  5.0E-3    P45_pork
  1.4E-1    P45_eggs
  1.0E-2    P45_chicken
 3.92E-9    P39
 1.12E-6    P49_adult
 3.65E-6    P49_inf
 9.57E-7    P59_milk_ad
 9.57E-6    P59_milk_inf
 1.95E-7    P59_beef_ad
 5.22E-7    P59_beef_inf
 1.95E-7    P59_pork_ad
 5.22E-7    P59_pork_inf
 3.85E-8    P59_eggs_ad
 2.18E-7    P59_eggs_inf
  8.8E-8    P59_chkn_ad
 4.35E-7    P59_chkn_inf
    50.0    P26_frfsh      :: Water source
    20.0    P26_ocnfsh
    50.0    P26_crust,mollusc
  7.8E-2    P27
       0    P28
       0    P69_frfsh
 1.32E-7    P69_ocnfsh
  4.4E-8    P69_crst,mllsc
  8.8E-9    P79
       0    P89
     1.0    RD(02)
       0    P(i)29_adult
       0    P(i)29_inf
       0    P(e)29
       0    P69,79_inf
 1.04E-7
 3.48E-8
 6.96E-9
*
```

```
** file I129.ptlp.loc ** Pmn parameters for program cldosl - I129
*
 6.6E-10       0    :: emission in Air (Bq/sec), Water (Bq/L)
*
 6.47E-4   P(i)19_ad  ::  Transfer parameters for air source
 2.52E-4   P(i)19_inf
 1.04E-8   P(e)19
 4.55E+7   P13
 4.82E+4   P14_forage
 1.18E+4   P14_crops
      2.8  P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
      4.5  P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  1.0E-1   P45_milk
  3.6E-2   P45_beef
  1.0E-2   P45_pork
  2.8E-1   P45_eggs
  2.0E-2   P45_chicken
2.14E-10   P39
 7.94E-6   P49_adult
 3.65E-6   P49_inf
 6.79E-6   P59_milk_ad
 1.98E-5   P59_milk_inf
 1.38E-6   P59_beef_ad
 1.08E-6   P59_beef_inf
 1.38E-6   P59_pork_ad
 1.08E-6   P59_pork_inf
 2.73E-7   P59_eggs_ad
 4.51E-7   P59_eggs_inf
 6.24E-7   P59_chkn_ad
 9.00E-7   P59_chkn_inf
    50.0   P26_frfsh     :: Water source (not used)
    20.0   P26_ocnfsh
    50.0   P26_crust,mollusc
  7.8E-2   P27
       0   P28
       0   P69_frfsh
 1.32E-7   P69_ocnfsh
  4.4E-8   P69_crst,mllsc
  8.8E-9   P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0
       0
       0
       0
*
```

```
** file Zn65.ptlp.loc ** Pmn parameters for program cldosl - Zn65
*
       0  4.6E-3     !! emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  !!  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
 3.92E-9   P39
 1.12E-6   P49_adult
 3.65E-6   P49_inf
 9.57E-7   P59_milk_ad
 9.57E-6   P59_milk_inf
 1.95E-7   P59_beef_ad
 5.22E-7   P59_beef_inf
 1.95E-7   P59_pork_ad
 5.22E-7   P59_pork_inf
 3.85E-8   P59_eggs_ad
 2.19E-7   P59_eggs_inf
  8.8E-8   P59_chkn_ad
 4.35E-7   P59_chkn_inf
  2.0E+2   P26_frfsh      !! Water source
  5.0E+3   P26_ocnfsh
 1.25E+4   P26_crust,mollusc
 4.30E+2   P27
       0   P28
       0   P69_frfsh
 4.80E-8   P69_ocnfsh
  1.6E-8   P69_crst,mllsc
 3.20E-9   P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0
 1.20E-8
 .400E-8
 .800E-9
*
```

```
** file Zr95.ptlp.loc ** Pmn parameters for program cldosl - Zr_Nb_95
*
      0  4.6E-3    :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  ::  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
 8.8E-8    P59_chkn_ad
4.35E-7    P59_chkn_inf
 2.0E+2    P26_frfsh      :: Water source
 1.0E+0    P26_ocnfsh
5.10E+1    P26_crust,mollusc
6.80E+3    P27
       0   P28
       0   P69_frfsh
5.87E-8    P69_ocnfsh
1.96E-8    P69_crst,mllsc
3.91E-9    P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0
.791E-8
.264E-8
.528E-9
*
```

```
** file Sr89.ptlp.loc ** Pmn parameters for program cldosl - Sr89
*
       0  4.6E-3     :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  ::  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
 8.8E-8    P59_chkn_ad
4.35E-7    P59_chkn_inf
  2.0E+2   P26_frfsh      :: Water source
  1.0E+0   P26_ocnfsh
1.00E+0    P26_crust,mollusc
3.25E+0    P27
       0   P28
       0   P69_frfsh
3.00E-8    P69_ocnfsh
  1.0E-8   P69_crst,mllsc
2.00E-9    P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0   P69,79_inf
2.16E-8
0.72E-8
1.44E-9
*
```

```
** file Sr90.ptlp.loc ** Pmn parameters for program cldosl - Sr90
*
       0  4.6E-3    :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  ::  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
 8.8E-8    P59_chkn_ad
4.35E-7    P59_chkn_inf
  2.0E+2   P26_frfsh     :: Water source
  1.0E+0   P26_ocnfsh
 1.00E+0   P26_crust,mollusc
 5.00E+0   P27
       0   P28
       0   P69_frfsh
 4.08E-7   P69_ocnfsh
 1.36E-7   P69_crst,mllsc
 2.72E-8   P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0
 2.88E-7
 0.96E-7
 1.92E-7
*
```

```
** file Co60.ptlp.loc ** Pmn parameters for program cldosl - Co60
*
       0  4.6E-3     :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  ::  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
 8.8E-8    P59_chkn_ad
4.35E-7    P59_chkn_inf
  2.0E+2   P26_frfsh      :: Water source
  1.0E+2   P26_ocnfsh
  7.5E+2   P26_crust,mollusc
 4.90E+3   P27
       0   P28
       0   P69_frfsh
2.04E-7    P69_ocnfsh
 6.8E-8    P69_crst,mllsc
1.36E-8    P79
       0   P89
     1.0   RD(02)
       0   P(i)29_adult
       0   P(i)29_inf
       0   P(e)29
       0
.432E-7
1.44E-8
.288E-8
*
```

```
** file Fe59.ptlp.loc ** Pmn parameters for program cldosl - Fe59
*
       0  4.6E-3    :: emission in Air (Bq/sec), Water (Bq/L)
*
  9.1E-5   P(i)19_ad  ::  Transfer parameters for air source  (not used)
  1.2E-4   P(i)19_inf
 4.76E-7   P(e)19
  1.0E+4   P13
 2.23E+4   P14_forage
 4.55E+3   P14_crops
     2.8   P15_milk
  2.9E-1   P15_beef
  9.9E-2   P15_pork
     4.5   P15_eggs
  3.8E-1   P15_chicken
  4.0E-3   P34_forage
  3.0E-4   P34_crops
  5.0E-2   P45_milk
  1.8E-2   P45_beef
  5.0E-3   P45_pork
  1.4E-1   P45_eggs
  1.0E-2   P45_chicken
3.92E-9    P39
1.12E-6    P49_adult
3.65E-6    P49_inf
9.57E-7    P59_milk_ad
9.57E-6    P59_milk_inf
1.95E-7    P59_beef_ad
5.22E-7    P59_beef_inf
1.95E-7    P59_pork_ad
5.22E-7    P59_pork_inf
3.85E-8    P59_eggs_ad
2.18E-7    P59_eggs_inf
  8.8E-8   P59_chkn_ad
4.35E-7    P59_chkn_inf
  2.0E+2   P26_frfsh      :: Water source
  3.0E+3   P26_ocnfsh
  6.0E+3   P26_crust,mollusc
  6.3E+2   P27
         0  P28
         0  P69_frfsh
2.16E-8    P69_ocnfsh
  7.2E-9   P69_crst,mllsc
1.44E-9    P79
         0  P89
       1.0  RD(02)
         0  P(i)29_adult
         0  P(i)29_inf
         0  P(e)29
         0
 .540E-8
 1.80E-9
 .360E-9
*
```

Table D.4 - Spatial Distribution of Individual and Collective Doses for the Darlington Site

Local Air Dose Rates for Nuclide C-14 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.1200E+06 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1951E-06	0.4878E-05	0.1171E-05	0.0000E+00
7.5	0.8536E-06	0.1778E-05	0.1707E-05	0.0000E+00
15.0	0.4715E-06	0.7367E-06	0.7072E-06	0.0000E+00
25.0	0.1187E-06	0.3709E-06	0.3561E-06	0.0000E+00
35.0	0.5235E-07	0.1402E-06	0.4487E-06	0.0000E+00
45.0	0.8848E-07	0.3353E-06	0.3219E-06	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.5121E-06	0.1707E-06
7.5	0.0000E+00	0.0000E+00	0.2241E-05	0.4979E-06
15.0	0.0000E+00	0.0000E+00	0.4332E-05	0.6188E-06
25.0	0.0000E+00	0.0000E+00	0.1246E-05	0.2077E-06
35.0	0.0000E+00	0.0000E+00	0.2354E-05	0.2618E-06
45.0	0.0000E+00	0.0000E+00	0.5434E-05	0.1078E-06

Rad(km)	Tot Rad Coll Dose
2.5	0.6926E-05
7.5	0.7078E-05
15.0	0.6866E-05
25.0	0.2380E-05
35.0	0.3299E-05
45.0	0.6559E-05

Total Collective dose : 0.3299E-04 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.1200E+06 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1981E-09	0.6192E-09	0.1189E-08	0.6935E-09
7.5	0.5779E-10	0.1806E-09	0.3468E-09	0.2027E-09
15.0	0.2394E-10	0.7482E-10	0.1437E-09	0.8380E-10
25.0	0.1205E-10	0.3767E-10	0.7232E-10	0.4219E-10
35.0	0.7596E-11	0.2374E-10	0.4557E-10	0.2658E-10
45.0	0.5449E-11	0.1703E-10	0.3269E-10	0.1907E-10

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.6448E-09	0.7438E-09	0.5281E-09	0.1734E-09
7.5	0.1878E-09	0.2167E-09	0.1517E-09	0.5057E-10
15.0	0.7781E-10	0.8978E-10	0.6285E-10	0.2095E-10
25.0	0.3917E-10	0.4520E-10	0.3164E-10	0.1055E-10
35.0	0.2469E-10	0.2848E-10	0.1994E-10	0.6646E-11
45.0	0.1771E-10	0.2043E-10	0.1430E-10	0.4768E-11

Local Liquid Dose Rates for Nuclide C-14 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.2000E-01 Bq

	Sector (clockwise from N)			
Rad(km)	1	2	3	4
2.5	0.1673E-05	0.1338E-04	0.0000E+00	0.0000E+00
7.5	0.2509E-04	0.1673E-04	0.0000E+00	0.0000E+00
15.0	0.3345E-04	0.0000E+00	0.0000E+00	0.0000E+00
25.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

	Sector (clockwise from N)			
Rad(km)	5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7.5	0.0000E+00	0.0000E+00	0.2509E-04	0.1673E-04
15.0	0.0000E+00	0.0000E+00	0.1171E-03	0.5018E-04
25.0	0.0000E+00	0.0000E+00	0.6690E-04	0.3345E-04
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

Rad(km)	Tot Rd Col Air Dose	Tot Rd Col Liq Dose	Tot (Gas & Liq dose)
2.5	0.6926E-05	0.1505E-04	0.2198E-04
7.5	0.7078E-05	0.8363E-04	0.9071E-04
15.0	0.6866E-05	0.2007E-03	0.2076E-03
25.0	0.2300E-05	0.1004E-03	0.1027E-03
35.0	0.3259E-05	0.0000E+00	0.3259E-05
45.0	0.6559E-05	0.0000E+00	0.6559E-05

Total Collective Air dose : 0.3299E-04 man-Sv/year

Total Collective Liquid dose : 0.3997E-03 man-Sv/year

Total Collective (Air & Liquid dose) : 0.4327E-03 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.2000E-01 Bq

	Sector (clockwise from N)			
Rad(km)	1	2	3	4
2.5	0.1656E-08	0.1656E-08	0.0000E+00	0.0000E+00
7.5	0.1656E-08	0.1656E-08	0.0000E+00	0.0000E+00
15.0	0.1656E-08	0.0000E+00	0.0000E+00	0.0000E+00
25.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

	Sector (clockwise from N)			
Rad(km)	5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7.5	0.0000E+00	0.0000E+00	0.1656E-08	0.1656E-08
15.0	0.0000E+00	0.0000E+00	0.1656E-08	0.1656E-08
25.0	0.0000E+00	0.0000E+00	0.1656E-08	0.1656E-08
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

Local Air Dose Rates for Nuclide HTvp ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.6300E+08 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7868E-03	0.1965E-01	0.4716E-02	0.0000E+00
7.5	0.3439E-02	0.7164E-02	0.6877E-02	0.0000E+00
15.0	0.1899E-02	0.2968E-02	0.2849E-02	0.0000E+00
25.0	0.4781E-03	0.1494E-02	0.1434E-02	0.0000E+00
35.0	0.2189E-03	0.5649E-03	0.1808E-02	0.0000E+00
45.0	0.3242E-03	0.1351E-02	0.1297E-02	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.2863E-02	0.6877E-03
7.5	0.0000E+00	0.0000E+00	0.9027E-02	0.2006E-02
15.0	0.0000E+00	0.0000E+00	0.1745E-01	0.2493E-02
25.0	0.0000E+00	0.0000E+00	0.5021E-02	0.8368E-03
35.0	0.0000E+00	0.0000E+00	0.9491E-02	0.1055E-02
45.0	0.0000E+00	0.0000E+00	0.2270E-01	0.7565E-03

Rad(km)	Tot Rad Coll Dose
2.5	0.2790E-01
7.5	0.2851E-01
15.0	0.2766E-01
25.0	0.9264E-02
35.0	0.1313E-01
45.0	0.2642E-01

Total Collective dose : 0.1329E+00 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.6300E+08 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7983E-06	0.2495E-05	0.4798E-05	0.2794E-05
7.5	0.2328E-06	0.7276E-06	0.1397E-05	0.8158E-06
15.0	0.9647E-07	0.3015E-06	0.5788E-06	0.3376E-06
25.0	0.4857E-07	0.1518E-06	0.2914E-06	0.1700E-06
35.0	0.3060E-07	0.9563E-07	0.1836E-06	0.1071E-06
45.0	0.2195E-07	0.6861E-07	0.1317E-06	0.7684E-07

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.2595E-05	0.2994E-05	0.2896E-05	0.6985E-06
7.5	0.7568E-06	0.8732E-06	0.8112E-06	0.2037E-06
15.0	0.3135E-06	0.3617E-06	0.3532E-06	0.8441E-07
25.0	0.1578E-06	0.1821E-06	0.1779E-06	0.4249E-07
35.0	0.9946E-07	0.1148E-06	0.1121E-06	0.2678E-07
45.0	0.7135E-07	0.8233E-07	0.8043E-07	0.1921E-07

Local Liquid Dose Rates for Nuclide H3vp ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.2300E+03 Bq/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7458E-03	0.5966E-02	0.4443E-06	0.0000E+00
7.5	0.1119E-01	0.7458E-02	0.2222E-05	0.0000E+00
15.0	0.1492E-01	0.4443E-05	0.2222E-05	0.0000E+00
25.0	0.4443E-05	0.4443E-05	0.2222E-05	0.0000E+00
35.0	0.3110E-05	0.2666E-05	0.4443E-05	0.0000E+00
45.0	0.6665E-05	0.8887E-05	0.4443E-05	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.4443E-06	0.4443E-06
7.5	0.0000E+00	0.0000E+00	0.1118E-01	0.7456E-02
15.0	0.0000E+00	0.0000E+00	0.5219E-01	0.2237E-01
25.0	0.0000E+00	0.0000E+00	0.2982E-01	0.1491E-01
35.0	0.0000E+00	0.0000E+00	0.5332E-04	0.1777E-04
45.0	0.0000E+00	0.0000E+00	0.1777E-03	0.1777E-04

Rad(km)	Tot Rd Col Air Dose	Tot Rd Col Liq Dose	Tot (Gas & Liq dose)
2.5	0.2790E-01	0.6713E-02	0.3462E-01
7.5	0.2851E-01	0.3729E-01	0.6580E-01
15.0	0.2744E-01	0.8948E-01	0.1171E+00
25.0	0.9264E-02	0.4474E-01	0.5401E-01
35.0	0.1313E-01	0.8131E-04	0.1321E-01
45.0	0.2442E-01	0.2155E-03	0.2664E-01

Total Collective Air dose : 0.1329E+00 man-Sv/year

Total Collective Liquid dose : 0.1785E+00 man-Sv/year

Total Collective (Air & Liquid dose) : 0.3114E+00 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.2300E+03 Bq/L

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7410E-06	0.7410E-06	0.4443E-09	0.4443E-09
7.5	0.7410E-06	0.7410E-06	0.4443E-09	0.4443E-09
15.0	0.7410E-06	0.4443E-09	0.4443E-09	0.4443E-09
25.0	0.4443E-09	0.4443E-09	0.4443E-09	0.4443E-09
35.0	0.4443E-09	0.4443E-09	0.4443E-09	0.4443E-09
45.0	0.4443E-09	0.4443E-09	0.4443E-09	0.4443E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.4443E-09	0.4443E-09	0.4443E-09	0.4443E-09
7.5	0.4443E-09	0.4443E-09	0.7408E-06	0.7408E-06
15.0	0.4443E-09	0.4443E-09	0.7408E-06	0.7408E-06
25.0	0.4443E-09	0.4443E-09	0.7408E-06	0.7408E-06
35.0	0.4443E-09	0.4443E-09	0.4443E-09	0.4443E-09
45.0	0.4443E-09	0.4443E-09	0.4443E-09	0.4443E-09

Local Air Dose Rates for Nuclide I131 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.6300E+01 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3183E-07	0.7956E-06	0.1910E-04	0.0000E+00
7.5	0.1392E-06	0.2981E-06	0.2785E-06	0.0000E+00
15.0	0.7691E-07	0.1282E-06	0.1154E-06	0.0000E+00
25.0	0.1936E-07	0.6858E-07	0.5888E-07	0.0000E+00
35.0	0.8548E-08	0.2287E-07	0.7330E-07	0.0000E+00
45.0	0.1313E-07	0.5478E-07	0.5251E-07	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0394E-07	0.2705E-07
7.5	0.0000E+00	0.0000E+00	0.3655E-06	0.8120E-07
15.0	0.0000E+00	0.0000E+00	0.7046E-06	0.1809E-06
25.0	0.0000E+00	0.0000E+00	0.2873E-06	0.3308E-07
35.0	0.0000E+00	0.0000E+00	0.3843E-06	0.4270E-07
45.0	0.0000E+00	0.0000E+00	0.9190E-06	0.3867E-07

Rad(km)	Tot Rad Coll Dose
2.5	0.1178E-05
7.5	0.1154E-05
15.0	0.1120E-05
25.0	0.3751E-06
35.0	0.5316E-06
45.0	0.1070E-05

Total Collective dose : 0.5381E-05 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.6300E+01 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3161E-10	0.9879E-10	0.1897E-09	0.1104E-09
7.5	0.9220E-11	0.2881E-10	0.5532E-10	0.3227E-10
15.0	0.3828E-11	0.1194E-10	0.2292E-10	0.1337E-10
25.0	0.1923E-11	0.6018E-11	0.1154E-10	0.6731E-11
35.0	0.1212E-11	0.3787E-11	0.7271E-11	0.4241E-11
45.0	0.8694E-12	0.2717E-11	0.5216E-11	0.3043E-11

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.1827E-09	0.1185E-09	0.8798E-10	0.2768E-10
7.5	0.2997E-10	0.3458E-10	0.2420E-10	0.8048E-11
15.0	0.1241E-10	0.1432E-10	0.1003E-10	0.3342E-11
25.0	0.6258E-11	0.7212E-11	0.5048E-11	0.1683E-11
35.0	0.3938E-11	0.4544E-11	0.3181E-11	0.1060E-11
45.0	0.2825E-11	0.3260E-11	0.2282E-11	0.7607E-12

Local Liquid Dose Rates for Nuclide I-131 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.2000E-01 Bq/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3666E-04	0.2933E-03	0.2413E-06	0.0000E+00
7.5	0.5499E-03	0.3666E-03	0.1207E-05	0.0000E+00
15.0	0.7332E-03	0.2413E-05	0.1207E-05	0.0000E+00
25.0	0.2413E-05	0.2413E-05	0.1207E-05	0.0000E+00
35.0	0.1689E-05	0.1448E-05	0.2413E-05	0.0000E+00
45.0	0.3620E-05	0.4827E-05	0.2413E-05	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.2413E-06	0.2413E-06
7.5	0.0000E+00	0.0000E+00	0.4781E-03	0.3187E-03
15.0	0.0000E+00	0.0000E+00	0.2231E-02	0.9562E-03
25.0	0.0000E+00	0.0000E+00	0.1275E-02	0.6375E-03
35.0	0.0000E+00	0.0000E+00	0.2994E-04	0.9653E-05
45.0	0.0000E+00	0.0000E+00	0.9653E-04	0.9653E-05

Rad(km)	Tot Rd Col Air Dose	Tot Rd Col Liq Dose	Tot (Gas & Liq dose)
2.5	0.1130E-05	0.3307E-03	0.3318E-03
7.5	0.1154E-05	0.1715E-02	0.1716E-02
15.0	0.1130E-05	0.3924E-02	0.3925E-02
25.0	0.3751E-06	0.1918E-02	0.1919E-02
35.0	0.5316E-06	0.4416E-04	0.4470E-04
45.0	0.1070E-05	0.1170E-03	0.1181E-03

Total Collective Air dose : 0.5381E-05 man-Sv/year

Total Collective Liquid dose : 0.8049E-02 man-Sv/year

Total Collective (Air & Liquid dose) : 0.8054E-02 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.2000E-01 Bq/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3424E-07	0.3424E-07	0.2413E-09	0.2413E-09
7.5	0.3424E-07	0.3424E-07	0.2413E-09	0.2413E-09
15.0	0.3424E-07	0.2413E-09	0.2413E-09	0.2413E-09
25.0	0.2413E-09	0.2413E-09	0.2413E-09	0.2413E-09
35.0	0.2413E-09	0.2413E-09	0.2413E-09	0.2413E-09
45.0	0.2413E-09	0.2413E-09	0.2413E-09	0.2413E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.2413E-09	0.2413E-09	0.2413E-09	0.2413E-09
7.5	0.2413E-09	0.2413E-09	0.2977E-07	0.2977E-07
15.0	0.2413E-09	0.2413E-09	0.2977E-07	0.2977E-07
25.0	0.2413E-09	0.2413E-09	0.2977E-07	0.2977E-07
35.0	0.2413E-09	0.2413E-09	0.2413E-09	0.2413E-09
45.0	0.2413E-09	0.2413E-09	0.2413E-09	0.2413E-09

Local Air Dose Rates for Nuclide 1129 ** Inhalation **

** Coll equiv dose rate (man-Sv/year) ** Source in Air : 0.3200E-07 Bq/m

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1275E-13	0.3184E-12	0.7647E-13	0.0000E+00
7.5	0.5576E-13	0.1162E-12	0.1115E-12	0.0000E+00
15.0	0.3888E-13	0.4813E-13	0.4628E-13	0.0000E+00
25.0	0.7753E-14	0.2423E-13	0.2326E-13	0.0000E+00
35.0	0.3428E-14	0.9161E-14	0.2931E-13	0.0000E+00
45.0	0.5257E-14	0.2191E-13	0.2107E-13	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.3346E-13	0.1115E-13
7.5	0.0000E+00	0.0000E+00	0.1444E-12	0.3257E-13
15.0	0.0000E+00	0.0000E+00	0.2838E-12	0.4043E-13
25.0	0.0000E+00	0.0000E+00	0.8141E-13	0.1357E-13
35.0	0.0000E+00	0.0000E+00	0.1539E-12	0.1710E-13
45.0	0.0000E+00	0.0000E+00	0.3480E-12	0.1227E-13

Rad(km)	Tot Rad Coll Dose
2.5	0.4529E-12
7.5	0.4623E-12
15.0	0.4485E-12
25.0	0.1502E-12
35.0	0.2129E-12
45.0	0.4289E-12

Total Collective dose : 0.2155E-11 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in Air : 0.3200E-07 Bq/m

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1276E-16	0.3987E-16	0.7656E-16	0.4467E-16
7.5	0.3722E-17	0.1163E-16	0.2233E-16	0.1303E-16
15.0	0.1542E-17	0.4818E-17	0.9251E-17	0.5396E-17
25.0	0.7762E-18	0.2426E-17	0.4657E-17	0.2717E-17
35.0	0.4891E-18	0.1529E-17	0.2935E-17	0.1712E-17
45.0	0.3589E-18	0.1897E-17	0.2185E-17	0.1275E-17

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.4147E-16	0.4785E-16	0.3349E-16	0.1116E-16
7.5	0.1210E-16	0.1396E-16	0.9749E-17	0.3256E-17
15.0	0.5011E-17	0.5782E-17	0.4047E-17	0.1349E-17
25.0	0.2523E-17	0.2911E-17	0.2039E-17	0.6798E-18
35.0	0.1590E-17	0.1834E-17	0.1284E-17	0.4280E-18
45.0	0.1168E-17	0.1314E-17	0.9211E-18	0.3070E-18

Local Air Dose Rates for Nuclide phase ** Radiation

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.254[illegible]+00 Pa-h

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1544E-02	0.3861E-01	0.9266E-02	0.0000E+00
7.5	0.4787E-02	0.1408E-01	0.1351E-01	0.0000E+00
15.0	0.3733E-02	0.5832E-02	0.5599E-02	0.0000E+00
25.0	0.9395E-03	0.2936E-02	0.2819E-02	0.0000E+00
35.0	0.4144E-03	0.1110E-02	0.3552E-02	0.0000E+00
45.0	0.6371E-03	0.2654E-02	0.2548E-02	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.4854E-02	0.1[illegible]1E-02
7.5	0.0000E+00	0.0000E+00	0.1774E-01	0.3941E-02
15.0	0.0000E+00	0.0000E+00	0.3429E-01	0.[illegible]99E-02
25.0	0.0000E+00	0.0000E+00	0.9865E-02	0.1644E-02
35.0	0.0000E+00	0.0000E+00	0.1065E-01	0.2872E-02
45.0	0.0000E+00	0.0000E+00	0.4459E-01	0.1486E-02

Rad(km)	Tot Rad Coll Dose
2.5	0.5483E-01
7.5	0.5[illegible]0.E-01
15.0	0.9435E-01
25.0	0.1820E-01
35.0	0.2580E-01
45.0	0.5192E-01

Total Collective dose : 0.2611E+00 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.254[illegible]+00 Pa-Hr/m

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1522E-05	0.4755E-05	0.9129E-05	0.5329E-05
7.5	0.4478E-06	0.1387E-05	0.2667E-05	0.1553E-05
15.0	0.1839E-06	0.5745E-06	0.1103E-05	0.6432E-06
25.0	0.9256E-07	0.2893E-06	0.5554E-06	0.3240E-06
35.0	0.5833E-07	0.1823E-06	0.3500E-06	0.2041E-06
45.0	0.4184E-07	0.1308E-06	0.2511E-06	0.1[illegible]6E-06

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.4945E-05	0.5704E-05	0.3994E-05	0.1211E-05
7.5	0.1442E-05	0.1664E-05	0.1165E-05	0.3531E-06
15.0	0.5975E-06	0.6895E-06	0.4824E-06	0.1[illegible]9E-06
25.0	0.3008E-06	0.3471E-06	0.2430E-06	0.9093E-07
35.0	0.1896E-06	0.2187E-06	0.1531E-06	0.5104E-07
45.0	0.1360E-06	0.1569E-06	0.1098E-06	0.3[illegible]1E-07

Local Air Dose Rates for Nuclide Co60 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in Air : 0.2200E+01 Ta/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1320E-05	0.3299E-04	0.7918E-05	0.0000E+00
7.5	0.5774E-05	0.1283E-04	0.1155E-04	0.0000E+00
15.0	0.3189E-05	0.4983E-05	0.4784E-05	0.0000E+00
25.0	0.8028E-06	0.2589E-05	0.2488E-05	0.0000E+00
35.0	0.3541E-06	0.9485E-06	0.3835E-05	0.0000E+00
45.0	0.5444E-06	0.2268E-05	0.2177E-05	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.3444E-05	0.1155E-05
7.5	0.0000E+00	0.0000E+00	0.1518E-04	0.3368E-05
15.0	0.0000E+00	0.0000E+00	0.2930E-04	0.4184E-05
25.0	0.0000E+00	0.0000E+00	0.8430E-05	0.1405E-05
35.0	0.0000E+00	0.0000E+00	0.1594E-04	0.1771E-05
45.0	0.0000E+00	0.0000E+00	0.3811E-04	0.1270E-05

Rad(km)	Tot Rad Coll Dose
2.5	0.4485E-04
7.5	0.4787E-04
15.0	0.4644E-04
25.0	0.1555E-04
35.0	0.2284E-04
45.0	0.4437E-04

Total Collective dose : 0.2231E-03 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.2200E+01 Ta/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1321E-08	0.4127E-08	0.7923E-08	0.4622E-08
7.5	0.3852E-09	0.1204E-08	0.2311E-08	0.1348E-08
15.0	0.1596E-09	0.4986E-09	0.9574E-09	0.5585E-09
25.0	0.8033E-10	0.2510E-09	0.4820E-09	0.2812E-09
35.0	0.5862E-10	0.1832E-09	0.3517E-09	0.2052E-09
45.0	0.3631E-10	0.1135E-09	0.2179E-09	0.1271E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.4292E-08	0.4952E-08	0.3464E-08	0.1155E-08
7.5	0.1252E-08	0.1444E-08	0.1011E-08	0.3370E-09
15.0	0.5186E-09	0.5984E-09	0.4189E-09	0.1396E-09
25.0	0.2611E-09	0.3012E-09	0.2109E-09	0.7029E-10
35.0	0.1445E-09	0.1668E-09	0.1168E-09	0.3893E-10
45.0	0.1180E-09	0.1362E-09	0.9534E-10	0.3178E-10

Local Liquid Dose Rates for Nuclide Co60 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.1000E-01 Bq/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1825E-03	0.1460E-02	0.1275E-03	0.0000E+00
7.5	0.2738E-02	0.1825E-02	0.6375E-03	0.0000E+00
15.0	0.3651E-02	0.1275E-02	0.6375E-03	0.0000E+00
25.0	0.1275E-02	0.1275E-02	0.6375E-03	0.0000E+00
35.0	0.8925E-03	0.7650E-03	0.1275E-02	0.0000E+00
45.0	0.1913E-02	0.2550E-02	0.1275E-02	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.1275E-03	0.1275E-03
7.5	0.0000E+00	0.0000E+00	0.2738E-02	0.1825E-02
15.0	0.0000E+00	0.0000E+00	0.1278E-01	0.5475E-02
25.0	0.0000E+00	0.0000E+00	0.7301E-02	0.3650E-02
35.0	0.0000E+00	0.0000E+00	0.1530E-01	0.5100E-02
45.0	0.0000E+00	0.0000E+00	0.5100E-01	0.5100E-02

Rad(km)	Tot Rd Col Air Dose	Tot Rd Col Liq Dose	Tot (Air & Liq dose
2.5	0.4485E-04	0.2025E-02	0.2070E-02
7.5	0.4787E-04	0.9764E-02	0.9812E-02
15.0	0.4644E-04	0.2382E-01	0.2389E-01
25.0	0.1555E-04	0.1414E-01	0.1415E-01
35.0	0.2204E-04	0.2333E-01	0.2375E-01
45.0	0.4437E-04	0.6194E-01	0.6198E-01

Total Collective Air dose : 0.2231E-03 man-Sv/year

Total Collective Liquid dose : 0.1349E+00 man-Sv/year

Total Collective (Air & Liquid dose) : 0.1351E+00 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.1000E-01 Bq/l

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1827E-06	0.1827E-06	0.1275E-06	0.1275E-06
7.5	0.1827E-06	0.1827E-06	0.1275E-06	0.1275E-06
15.0	0.1827E-06	0.1275E-06	0.1275E-06	0.1275E-06
25.0	0.1275E-06	0.1275E-06	0.1275E-06	0.1275E-06
35.0	0.1275E-06	0.1275E-06	0.1275E-06	0.1275E-06
45.0	0.1275E-06	0.1275E-06	0.1274E-06	0.1274E-06

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.1275E-06	0.1275E-06	0.1275E-06	0.1275E-06
7.5	0.1275E-06	0.1275E-06	0.1827E-06	0.1827E-06
15.0	0.1275E-06	0.1275E-06	0.1827E-06	0.1827E-06
25.0	0.1275E-06	0.1275E-06	0.1827E-06	0.1827E-06
35.0	0.1275E-06	0.1275E-06	0.1275E-06	0.1275E-06
45.0	0.1275E-06	0.1275E-06	0.1275E-06	0.1275E-06

Local Air Dose Rates for Nuclide Sr89 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.2200E+01 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.9229E-08	0.2387E-06	0.5538E-07	0.0000E+00
7.5	0.4038E-07	0.8412E-07	0.8076E-07	0.0000E+00
15.0	0.2230E-07	0.3485E-07	0.3346E-07	0.0000E+00
25.0	0.5615E-08	0.1755E-07	0.1684E-07	0.0000E+00
35.0	0.2477E-08	0.6634E-08	0.2103E-07	0.0000E+00
45.0	0.3807E-08	0.1586E-07	0.1523E-07	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.2427E-07	0.8076E-08
7.5	0.0000E+00	0.0000E+00	0.1060E-06	0.2355E-07
15.0	0.0000E+00	0.0000E+00	0.2849E-06	0.2927E-07
25.0	0.0000E+00	0.0000E+00	0.5895E-07	0.9826E-08
35.0	0.0000E+00	0.0000E+00	0.1114E-06	0.1238E-07
45.0	0.0000E+00	0.0000E+00	0.2665E-06	0.8883E-08

Rad(km)	Tot Rad Coll Dose
2.5	0.3276E-06
7.5	0.3348E-06
15.0	0.3248E-06
25.0	0.1088E-06
35.0	0.1542E-06
45.0	0.3103E-06

Total Collective dose : 0.1560E-05 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.2200E+01 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.9293E-11	0.2984E-10	0.5576E-10	0.3252E-10
7.5	0.2718E-11	0.8478E-11	0.1626E-10	0.9484E-11
15.0	0.1123E-11	0.3509E-11	0.6737E-11	0.3930E-11
25.0	0.3653E-12	0.1767E-11	0.3392E-11	0.1979E-11
35.0	0.3542E-12	0.1113E-11	0.2137E-11	0.1247E-11
45.0	0.2556E-12	0.7986E-12	0.1533E-11	0.8944E-12

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.3020E-10	0.3485E-10	0.2439E-10	0.8131E-11
7.5	0.8089E-11	0.1016E-10	0.7115E-11	0.2372E-11
15.0	0.3649E-11	0.4211E-11	0.2948E-11	0.9825E-12
25.0	0.1837E-11	0.2120E-11	0.1484E-11	0.4946E-12
35.0	0.1150E-11	0.1334E-11	0.9351E-12	0.3117E-12
45.0	0.8305E-12	0.9587E-12	0.6700E-12	0.2234E-12

Local Liquid Dose Rates for Nuclide SrB9 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.2000E-01 P

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.8720E-05	0.6976E-04	0.3656E-11	0.0000E+00
7.5	0.1308E-03	0.8720E-04	0.1828E-10	0.0000E+00
15.0	0.1744E-03	0.3656E-10	0.1828E-10	0.0000E+00
25.0	0.3656E-10	0.3656E-10	0.1828E-10	0.0000E+00
35.0	0.2559E-10	0.2194E-10	0.3656E-10	0.0000E+00
45.0	0.5485E-10	0.7313E-10	0.3656E-10	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.3656E-11	0.3656E-11
7.5	0.0000E+00	0.0000E+00	0.1279E-03	0.8570E-04
15.0	0.0000E+00	0.0000E+00	0.5971E-03	0.2[illegible]E-03
25.0	0.0000E+00	0.0000E+00	0.3412E-03	0.1706E-03
35.0	0.0000E+00	0.0000E+00	0.4380E-09	0.1461E-09
45.0	0.0000E+00	0.0000E+00	0.1463E-03	0.1463E-09

Rad(km)	Tot Rd Col Air Dose	Tot Rd Col Liq Dose	Tot (Air & Liq dose)
2.5	0.3276E-06	0.7848E-04	0.7[illegible]E-04
7.5	0.3348E-06	0.4313E-03	0.4716E-03
15.0	0.3248E-06	0.1027E-02	0.1[illegible]E-02
25.0	0.1809E-06	0.5110E-03	0.5[illegible]E-03
35.0	0.1542E-06	0.6491E-09	0.1543E-06
45.0	0.3103E-06	0.1773E-08	0.3101E-06

Total Collective Air dose : 0.1568E-05 man-Sv/year

Total Collective Liquid dose : 0.2049E-02 man-Sv/year

Total Collective (Air & Liquid dose) : 0.2050E-0[illegible] man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.2000E-01 Bq/l

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.8227E-08	0.8227E-08	0.3656E-14	0.3656E-14
7.5	0.8227E-08	0.8227E-08	0.3656E-14	0.3656E-14
15.0	0.8227E-08	0.3656E-14	0.3656E-14	0.3656E-14
25.0	0.3656E-14	0.3656E-14	0.3656E-14	0.3656E-14
35.0	0.3656E-14	0.3656E-14	0.3656E-14	0.3656E-14
45.0	0.3656E-14	0.3656E-14	0.3656E-14	0.3656E-14

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.3656E-14	0.3656E-14	0.3656E-14	0.3656E-14
7.5	0.3656E-14	0.3656E-14	0.8047E-08	0.8047E-08
15.0	0.3656E-14	0.3656E-14	0.8047E-08	0.8047E-08
25.0	0.3656E-14	0.3656E-14	0.8047E-08	0.8047E-08
35.0	0.3656E-14	0.3656E-14	0.3656E-14	0.3656E-14
45.0	0.3656E-14	0.3656E-14	0.3656E-14	0.3656E-14

Local Air Dose Rates for Nuclide Sr90 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.2000E+01 Bq/m

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2937E-06	0.7341E-05	0.1762E-05	0.0000E+00
7.5	0.1285E-05	0.2677E-05	0.2569E-05	0.0000E+00
15.0	0.7097E-06	0.1109E-05	0.1064E-05	0.0000E+00
25.0	0.1786E-06	0.5582E-06	0.5359E-06	0.0000E+00
35.0	0.7880E-07	0.2111E-06	0.2754E-06	0.0000E+00
45.0	0.1211E-06	0.5847E-06	0.4845E-06	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.7708E-06	0.[illegible]E-06
7.5	0.0000E+00	0.0000E+00	0.3372E-05	0.7494E-06
15.0	0.0000E+00	0.0000E+00	0.[illegible]E-05	0.[illegible]E-06
25.0	0.0000E+00	0.0000E+00	0.1076E-05	0.[illegible]E-06
35.0	0.0000E+00	0.0000E+00	0.3546E-05	0.3940E-06
45.0	0.0000E+00	0.0000E+00	0.8479E-05	0.[illegible]E-06

Rad(km)	Tot Rad Coll Dose
2.5	0.1042E-04
7.5	0.1065E-04
15.0	0.1033E-04
25.0	0.3461E-05
35.0	0.4985E-05
45.0	0.9872E-05

Total Collective dose : 0.4965E-04 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.2000E+01 Bq/m

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2957E-09	0.9240E-09	0.1774E-09	0.1075E-09
7.5	0.8624E-10	0.2699E-09	0.5174E-09	0.7019E-09
15.0	0.3573E-10	0.1117E-09	0.2144E-09	0.1[illegible]E-09
25.0	0.1799E-10	0.5621E-10	0.1079E-09	0.6296E-10
35.0	0.1133E-10	0.3542E-10	0.6801E-10	0.3967E-10
45.0	0.8131E-11	0.2541E-10	0.4879E-10	0.2846E-10

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.9610E-09	0.1189E-09	0.7762E-09	0.2587E-09
7.5	0.2803E-09	0.3234E-09	0.2264E-09	0.7544E-10
15.0	0.1161E-09	0.1348E-09	0.9379E-10	0.3126E-10
25.0	0.5846E-10	0.6749E-10	0.4720E-10	0.1574E-10
35.0	0.3684E-10	0.4258E-10	0.2975E-10	0.9918E-11
45.0	0.2643E-10	0.[illegible]E-10	0.2134E-10	0.7115E-11

Local Liquid Dose Rates for Nuclide Sr90 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 3.2000E-01 Bq

	Sector (clockwise from N)			
Rad(km)	1	2	3	4
2.5	0.1170E-03	0.9362E-03	0.0000E+00	0.0000E+00
7.5	0.1755E-02	0.1170E-02	0.0000E+00	0.0000E+00
15.0	0.2340E-02	0.0000E+00	0.0000E+00	0.0000E+00
25.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

	Sector (clockwise from N)			
Rad(km)	5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7.5	0.0000E+00	0.0000E+00	0.1755E-02	0.1170E-02
15.0	0.0000E+00	0.0000E+00	0.2191E-02	0.3510E-02
25.0	0.0000E+00	0.0000E+00	0.4680E-02	0.2340E-02
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

Rad(km)	Tot Rd Col Air Dose	Tot Rd Col Liq Dose	Tot (Gas & Liq dose)
2.5	0.1042E-04	0.1053E-02	0.1064E-02
7.5	0.1065E-04	0.5851E-02	0.5958E-02
15.0	0.1033E-04	0.1404E-01	0.1405E-01
25.0	0.3441E-05	0.7020E-02	0.7024E-02
35.0	0.4965E-05	0.0000E+00	0.4965E-05
45.0	0.9872E-05	0.0000E+00	0.9872E-05

Total Collective Air dose : 0.4965E-04 man-Sv/year

Total Collective Liquid dose : 0.2797E-01 man-Sv/year

Total Collective (Air & Liquid dose) : 0.2802E-01 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 3.2000E-01 Bq/L

	Sector (clockwise from N)			
Rad(km)	1	2	3	4
2.5	0.1184E-06	0.1184E-06	0.0000E+00	0.0000E+00
7.5	0.1184E-06	0.1184E-06	0.0000E+00	0.0000E+00
15.0	0.1184E-06	0.0000E+00	0.0000E+00	0.0000E+00
25.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

	Sector (clockwise from N)			
Rad(km)	5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7.5	0.0000E+00	0.0000E+00	0.1184E-06	0.1184E-06
15.0	0.0000E+00	0.0000E+00	0.1184E-06	0.1184E-06
25.0	0.0000E+00	0.0000E+00	0.1184E-06	0.1184E-06
35.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
45.0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

Local Liquid Dose Rates for Nuclide Zn65 ** Darlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.1000E-01 Bq/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1456E-04	0.1165E-03	0.1654E-05	0.0000E+00
7.5	0.2184E-03	0.1456E-03	0.8270E-05	0.0000E+00
15.0	0.2912E-03	0.1654E-04	0.8270E-05	0.0000E+00
25.0	0.1654E-04	0.1654E-04	0.8270E-05	0.0000E+00
35.0	0.1158E-04	0.9924E-05	0.1654E-04	0.0000E+00
45.0	0.2481E-04	0.3308E-04	0.1654E-04	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.1654E-05	0.1654E-05
7.5	0.0000E+00	0.0000E+00	0.2184E-03	0.1456E-03
15.0	0.0000E+00	0.0000E+00	0.1819E-03	0.4368E-03
25.0	0.0000E+00	0.0000E+00	0.5825E-03	0.2912E-03
35.0	0.0000E+00	0.0000E+00	0.1985E-03	0.6616E-04
45.0	0.0000E+00	0.0000E+00	0.6616E-03	0.6616E-04

Rad(km)	Tot Rad Coll Dose
2.5	0.1360E-03
7.5	0.7363E-03
15.0	0.1772E-02
25.0	0.9150E-03
35.0	0.3027E-03
45.0	0.8822E-03

Total Collective Liquid dose : 0.4664E-02 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.1000E-01 Bq/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1453E-07	0.1453E-07	0.1654E-08	0.1654E-08
7.5	0.1453E-07	0.1453E-07	0.1654E-08	0.1654E-08
15.0	0.1453E-07	0.1654E-08	0.1654E-08	0.1654E-08
25.0	0.1654E-08	0.1654E-08	0.1654E-08	0.1654E-08
35.0	0.1654E-08	0.1654E-08	0.1654E-08	0.1654E-08
45.0	0.1654E-08	0.1654E-08	0.1654E-08	0.1654E-08

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.1654E-08	0.1654E-08	0.1654E-08	0.1654E-08
7.5	0.1654E-08	0.1654E-08	0.1453E-07	0.1453E-07
15.0	0.1654E-08	0.1654E-08	0.1453E-07	0.1453E-07
25.0	0.1654E-08	0.1654E-08	0.1453E-07	0.1453E-07
35.0	0.1654E-08	0.1654E-08	0.1654E-08	0.1654E-08
45.0	0.1654E-08	0.1654E-08	0.1654E-08	0.1654E-08

Local Liquid Dose Rate for Nuclide Fe55 ** Burlington

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.2000E-01 Ba/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3850E-04	0.3880E-03	0.3255E-04	0.0000E+00
7.5	0.5775E-03	0.3850E-03	0.1627E-03	0.0000E+00
15.0	0.7699E-03	0.3255E-03	0.1627E-03	0.0000E+00
25.0	0.3255E-03	0.3255E-03	0.1627E-03	0.0000E+00
35.0	0.2278E-03	0.1953E-03	0.3255E-03	0.0000E+00
45.0	0.4882E-03	0.6509E-03	0.3255E-03	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.3255E-04	0.3255E-04
7.5	0.0000E+00	0.0000E+00	0.5752E-03	0.3835E-03
15.0	0.0000E+00	0.0000E+00	0.2684E-02	0.1150E-02
25.0	0.0000E+00	0.0000E+00	0.1534E-02	0.7670E-03
35.0	0.0000E+00	0.0000E+00	0.3986E-02	0.1302E-02
45.0	0.0000E+00	0.0000E+00	0.1302E-01	0.1302E-02

Rad(km)	Tot Rad Coll Dose
2.5	0.4441E-03
7.5	0.2084E-02
15.0	0.5093E-02
25.0	0.3115E-02
35.0	0.5956E-02
45.0	0.1579E-01

Total Collective Liquid dose : 0.3248E-01 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.2000E-01 Ba/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3848E-07	0.3848E-07	0.3255E-07	0.3255E-07
7.5	0.3848E-07	0.3848E-07	0.3255E-07	0.3255E-07
15.0	0.3848E-07	0.3255E-07	0.3255E-07	0.3255E-07
25.0	0.3255E-07	0.3255E-07	0.3255E-07	0.3255E-07
35.0	0.3255E-07	0.3255E-07	0.3255E-07	0.3255E-07
45.0	0.3255E-07	0.3255E-07	0.3255E-07	0.3255E-07

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.3255E-07	0.3255E-07	0.3255E-07	0.3255E-07
7.5	0.3255E-07	0.3255E-07	0.3834E-07	0.3834E-07
15.0	0.3255E-07	0.3255E-07	0.3834E-07	0.3834E-07
25.0	0.3255E-07	0.3255E-07	0.3834E-07	0.3834E-07
35.0	0.3255E-07	0.3255E-07	0.3834E-07	0.3834E-07
45.0	0.3255E-07	0.3255E-07	0.3834E-07	0.3834E-07

Local Liquid Dose Rates for Nuclide Zr95 ** Delineator

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.2000E-01 Bq

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7426E-04	0.5941E-03	0.7146E-04	0.0000E+00
7.5	0.1114E-02	0.7426E-03	0.3573E-03	0.0000E+00
15.0	0.1485E-02	0.7146E-03	0.3573E-03	0.0000E+00
25.0	0.7146E-03	0.7146E-03	0.3573E-03	0.0000E+00
35.0	0.5002E-03	0.4288E-03	0.7146E-03	0.0000E+00
45.0	0.1072E-02	0.1429E-02	0.7146E-03	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.7146E-04	0.7146E-04
7.5	0.0000E+00	0.0000E+00	0.1113E-02	0.7421E-03
15.0	0.0000E+00	0.0000E+00	0.5195E-02	0.2226E-02
25.0	0.0000E+00	0.0000E+00	0.2948E-02	0.1484E-02
35.0	0.0000E+00	0.0000E+00	0.0575E-02	0.2859E-02
45.0	0.0000E+00	0.0000E+00	0.2858E-01	0.2858E-02

Rad(km)	Tot Rad Coll Dose
2.5	0.8827E-03
7.5	0.4069E-02
15.0	0.9978E-02
25.0	0.6239E-02
35.0	0.1703E-01
45.0	0.3464E-01

Total Collective Liquid dose : 0.6890E-01 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.2000E-01 Bq/l

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7430E-07	0.7430E-07	0.7146E-07	0.7146E-07
7.5	0.7430E-07	0.7430E-07	0.7146E-07	0.7146E-07
15.0	0.7430E-07	0.7146E-07	0.7146E-07	0.7146E-07
25.0	0.7146E-07	0.7146E-07	0.7146E-07	0.7146E-07
35.0	0.7146E-07	0.7146E-07	0.7146E-07	0.7146E-07
45.0	0.7146E-07	0.7146E-07	0.7146E-07	0.7146E-07

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.7146E-07	0.7146E-07	0.7146E-07	0.7146E-07
7.5	0.7146E-07	0.7146E-07	0.7429E-07	0.7429E-07
15.0	0.7146E-07	0.7146E-07	0.7429E-07	0.7429E-07
25.0	0.7146E-07	0.7146E-07	0.7429E-07	0.7429E-07
35.0	0.7146E-07	0.7146E-07	0.7146E-07	0.7146E-07
45.0	0.7146E-07	0.7146E-07	0.7146E-07	0.7146E-07

Table D.5 - Spatial Distribution of Individual and Collective Doses for the Point Lepreau Site

Local Air Dose Rates for Nuclide C-14 ** Pt.-Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.2150E+35 Bq/y

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.4373E-07	0.7164E-07	0.0000E+00	0.0000E+00
7.5	0.1569E-06	0.3508E-07	0.0000E+00	0.0000E+00
12.5	0.9039E-07	0.8009E-07	0.0000E+00	0.0000E+00
17.5	0.2429E-07	0.1250E-06	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.1088E-05	0.0000E+00	0.0000E+00
35.0	0.5954E-06	0.2812E-04	0.3[illegible]E-07	0.0000E+00
45.0	0.4025E-06	0.3261E-05	0.6786E-07	0.0000E+00
55.0	0.1465E-06	0.4146E-05	0.2038E-06	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.676BE-07
7.5	0.0000E+00	0.0000E+00	0.2749E-07	0.[illegible]-07
12.5	0.0000E+00	0.0000E+00	0.[illegible]449E-06	0.3944E-07
17.5	0.0000E+00	0.0000E+00	0.7668E-07	0.1275E-07
22.5	0.0000E+00	0.0000E+00	0.6483E-06	0.2764E-07
27.5	0.0000E+00	0.0000E+00	0.8213E-06	0.1154E-06
35.0	0.1376E-06	0.5578E-06	0.540[illegible]E-06	0.6299E-07
45.0	0.9176E-07	0.5544E-06	0.1560E-05	0.1283E-06
55.0	0.9318E-07	0.8658E-06	0.5759E-06	0.1308E-06

Rad(km)	Tot Rad Coll Dose
2.5	0.1790E-06
7.5	0.3166E-06
12.5	0.6548E-06
17.5	0.2387E-06
22.5	0.6759E-06
27.5	0.2024E-05
35.0	0.3005E-04
45.0	0.6066E-05
55.0	0.6162E-05

Total Collective dose : 0.4637E-04 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.2150E+05 Pa/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.4402E-09	0.3958E-09	0.4917E-09	0.4544E-09
7.5	0.3459E-09	0.3329E-09	0.3609E-09	0.3500E-09
12.5	0.3270E-09	0.3204E-09	0.3347E-09	0.3292E-09
17.5	0.3204E-09	0.3159E-09	0.3255E-09	0.3218E-09
22.5	0.3165E-09	0.3133E-09	0.3201E-09	0.3175E-09
27.5	0.3142E-09	0.3118E-09	0.3169E-09	0.3149E-09
35.0	0.3122E-09	0.3105E-09	0.3141E-09	0.3127E-09
45.0	0.3107E-09	0.3095E-09	0.3121E-09	0.3111E-09
55.0	0.3098E-09	0.3089E-09	0.3109E-09	0.3101E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.3958E-09	0.3887E-09	0.4065E-09	0.3943E-09
7.5	0.3329E-09	0.3309E-09	0.3360E-09	0.3179E-09
12.5	0.3204E-09	0.3193E-09	0.3220E-09	0.3126E-09
17.5	0.3159E-09	0.3152E-09	0.3170E-09	0.3108E-09
22.5	0.3133E-09	0.3128E-09	0.3141E-09	0.3097E-09
27.5	0.3118E-09	0.3114E-09	0.3124E-09	0.3090E-09
35.0	0.3105E-09	0.3102E-09	0.3109E-09	0.3085E-09
45.0	0.3095E-09	0.3093E-09	0.3098E-09	0.3081E-09
55.0	0.3089E-09	0.3088E-09	0.3091E-09	0.3079E-09

Local Air Dose Rates for Nuclide [Typ ** Pt.-Leprau

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.6150E+01 Sv/y

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2821E-04	0.3417E-04	0.0000E+00	0.0000E+00
7.5	0.3733E-04	0.5779E-05	0.0000E+00	0.0000E+00
12.5	0.1170E-04	0.7060E-05	0.0000E+00	0.0000E+00
17.5	0.2141E-05	0.7466E-05	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.3534E-04	0.0000E+00	0.0000E+00
35.0	0.2001E-04	0.4639E-03	0.1484E-05	0.0000E+00
45.0	0.1020E-04	0.5582E-04	0.2360E-05	0.0000E+00
55.0	0.2037E-05	0.5437E-04	0.5414E-05	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.1461E-04
7.5	0.0000E+00	0.0000E+00	0.5026E-05	0.7050E-05
12.5	0.0000E+00	0.0000E+00	0.4369E-04	0.1506E-05
17.5	0.0000E+00	0.0000E+00	0.5108E-05	0.3287E-06
22.5	0.0000E+00	0.0000E+00	0.3096E-04	0.5104E-06
27.5	0.0000E+00	0.0000E+00	0.2979E-04	0.1622E-05
35.0	0.3246E-05	0.1214E-04	0.1422E-04	0.6464E-06
45.0	0.1571E-05	0.8758E-05	0.2978E-04	0.9645E-06
55.0	0.1222E-05	0.1049E-04	0.8419E-05	0.7611E-06

Rad(km)	Tot Rad Coll Dose
2.5	0.7700E-04
7.5	0.5519E-04
12.5	0.6395E-04
17.5	0.1504E-04
22.5	0.3147E-04
27.5	0.6679E-04
35.0	0.7161E-03
45.0	0.1095E-03
55.0	0.8351E-04

Total Collective dose : 0.1218E-02 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.6150E+07 Bq/m

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2924E-06	0.1950E-06	0.4054E-06	0.3236E-06
7.5	0.8540E-07	0.5698E-07	0.1184E-06	0.9449E-07
12.5	0.4399E-07	0.2938E-07	0.6095E-07	0.4867E-07
17.5	0.2938E-07	0.1964E-07	0.4068E-07	0.3250E-07
22.5	0.2086E-07	0.1396E-07	0.2886E-07	0.2307E-07
27.5	0.1574E-07	0.1055E-07	0.2177E-07	0.1741E-07
35.0	0.1136E-07	0.7626E-08	0.1569E-07	0.1256E-07
45.0	0.8194E-08	0.5515E-08	0.1130E-07	0.9052E-08
55.0	0.6246E-08	0.4216E-08	0.8600E-08	0.6895E-08

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.1950E-06	0.1794E-06	0.2184E-06	0.8199E-07
7.5	0.5698E-07	0.5244E-07	0.6380E-07	0.2403E-07
12.5	0.2938E-07	0.2704E-07	0.3289E-07	0.1243E-07
17.5	0.1964E-07	0.1808E-07	0.2198E-07	0.8340E-08
22.5	0.1396E-07	0.1285E-07	0.1561E-07	0.5954E-08
27.5	0.1055E-07	0.9717E-08	0.1180E-07	0.4502E-08
35.0	0.7626E-08	0.7029E-08	0.8522E-08	0.3294E-08
45.0	0.5515E-08	0.5087E-08	0.6158E-08	0.2400E-08
55.0	0.4216E-08	0.3892E-08	0.4704E-08	0.1862E-08

Local Liquid Dose Rates for Nuclide H3:p ** Pt.-Isotope

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.540[illegible]

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7653E-07	0.1390E-06	0.0000E+00	0.0000E+00
7.5	0.3467E-06	0.9843E-07	0.0000E+00	0.0000E+00
12.5	0.2100E-06	0.1905E-06	0.0000E+00	0.0000E+00
17.5	0.5778E-07	0.3014E-06	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.2656E-05	0.0000E+00	0.0000E+00
35.0	0.1452E-05	0.6896E-04	0.7496E-07	0.0000E+00
45.0	0.9862E-06	0.8020E-05	0.1655E-06	0.0000E+00
55.0	0.3600E-06	0.1022E-04	0.4990E-06	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.1413E-06
7.5	0.0000E+00	0.0000E+00	0.6247E-07	0.2327E-06
12.5	0.0000E+00	0.0000E+00	0.1053E-05	0.9605E-07
17.5	0.0000E+00	0.0000E+00	0.1843E-06	0.3124E-07
22.5	0.0000E+00	0.0000E+00	0.1572E-05	0.6794E-07
27.5	0.0000E+00	0.0000E+00	0.2002E-05	0.2042E-06
35.0	0.3373E-06	0.1369E-05	0.1323E-05	0.1554E-06
45.0	0.2257E-06	0.1364E-05	0.3833E-05	0.3170E-06
55.0	0.2296E-06	0.2134E-05	0.1418E-05	0.3233E-06

Rad(km)	Tot Rad Coll Air Dose	Tot Rad Coll Liq Dose	Tot (Gas and L
2.5	0.7700E-04	0.3569E-06	0.7735E-04
7.5	0.5519E-04	0.7223E-06	0.5591E-04
12.5	0.6395E-04	0.1551E-05	0.6550E-04
17.5	0.1504E-04	0.5747E-06	0.1562E-04
22.5	0.3147E-04	0.1640E-05	0.3311E-04
27.5	0.6675E-04	0.4942E-05	0.7169E-04
35.0	0.7161E-03	0.7347E-04	0.7897E-03
45.0	0.1095E-03	0.1491E-04	0.1244E-03
55.0	0.8351E-04	0.1518E-04	0.9869E-04

Total Collective Air dose : 0.1218E-02 man-Sv/year

Total Collective Liquid dose : 0.1136E-03 man-Sv/year

Total Collective (Air & Liquid dose) : 0.1332E-02 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.5400E-0? Ig/L

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
7.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
12.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
17.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
22.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
27.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
35.0	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
45.0	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
55.0	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
7.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
12.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
17.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
22.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
27.5	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
35.0	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
45.0	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09
55.0	0.7764E-09	0.7764E-09	0.7764E-09	0.7764E-09

Local Air Dose Rates for Nuclide I131 ** Pt.-Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.1310E+00 Bq/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2604E-09	0.3258E-09	0.0000E+00	0.0000E+00
7.5	0.3995E-09	0.6783E-10	0.0000E+00	0.0000E+00
12.5	0.1480E-09	0.1035E-09	0.0000E+00	0.0000E+00
17.5	0.3139E-10	0.1318E-09	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.8986E-09	0.0000E+00	0.0000E+00
35.0	0.5043E-09	0.2114E-07	0.2956E-10	0.0000E+00
45.0	0.3085E-09	0.2275E-08	0.5737E-10	0.0000E+00
55.0	0.1050E-09	0.2753E-08	0.1583E-09	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.1576E-07
7.5	0.0000E+00	0.0000E+00	0.5731E-10	0.1128E-09
12.5	0.0000E+00	0.0000E+00	0.6124E-09	0.3447E-10
17.5	0.0000E+00	0.0000E+00	0.8526E-10	0.9819E-11
22.5	0.0000E+00	0.0000E+00	0.6185E-09	0.1959E-10
27.5	0.0000E+00	0.0000E+00	0.7046E-09	0.7755E-10
35.0	0.1034E-09	0.4108E-09	0.4185E-09	0.4032E-10
45.0	0.6401E-10	0.3806E-09	0.1114E-08	0.7921E-10
55.0	0.6187E-10	0.5676E-09	0.3897E-09	0.7995E-10

Rad(km)	Tot Rad Coll Dose
2.5	0.7439E-09
7.5	0.6375E-09
12.5	0.8983E-09
17.5	0.2583E-09
22.5	0.6381E-09
27.5	0.1681E-08
35.0	0.2265E-07
45.0	0.4278E-08
55.0	0.4115E-08

Total Collective dose : 0.3590E-07 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.1310E+00 Bq-s

	Sector (clockwise from N)			
Rad(km)	1	2	3	4
2.5	0.2625E-11	0.1903E-11	0.3578E-11	0.2889E-11
7.5	0.8786E-12	0.6389E-12	0.1157E-11	0.9553E-12
12.5	0.5293E-12	0.4061E-12	0.6723E-12	0.5608E-12
17.5	0.4061E-12	0.3239E-12	0.5014E-12	0.4324E-12
22.5	0.3342E-12	0.2760E-12	0.4017E-12	0.3520E-12
27.5	0.2911E-12	0.2472E-12	0.3419E-12	0.3051E-12
35.0	0.2541E-12	0.2226E-12	0.2904E-12	0.2642E-12
45.0	0.2274E-12	0.2048E-12	0.2536E-12	0.2346E-12
55.0	0.2109E-12	0.1938E-12	0.2308E-12	0.2164E-12

	Sector (clockwise from N)			
Rad(km)	5	6	7	8
2.5	0.1803E-11	0.1671E-11	0.2000E-11	0.8498E-12
7.5	0.6389E-12	0.6006E-12	0.6964E-12	0.3609E-12
12.5	0.4061E-12	0.3864E-12	0.4357E-12	0.2631E-12
17.5	0.3239E-12	0.3108E-12	0.3436E-12	0.2298E-12
22.5	0.2760E-12	0.2667E-12	0.2900E-12	0.2085E-12
27.5	0.2472E-12	0.2402E-12	0.2577E-12	0.1964E-12
35.0	0.2226E-12	0.2175E-12	0.2301E-12	0.1840E-12
45.0	0.2048E-12	0.2012E-12	0.2102E-12	0.1786E-12
55.0	0.1938E-12	0.1911E-12	0.1979E-12	0.1740E-12

Local Liquid Dose Rates for Nuclide I131 ** Pt.-Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.4000E-03 Bq

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2148E-08	0.3938E-08	0.0000E+00	0.0000E+00
7.5	0.9824E-08	0.2279E-08	0.0000E+00	0.0000E+00
12.5	0.5974E-08	0.5399E-08	0.0000E+00	0.0000E+00
17.5	0.1637E-08	0.8541E-08	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.7525E-07	0.0000E+00	0.0000E+00
35.0	0.4116E-07	0.1954E-05	0.2124E-08	0.0000E+00
45.0	0.2705E-07	0.2273E-06	0.4691E-08	0.0000E+00
55.0	0.1030E-07	0.2895E-06	0.1414E-07	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.4005E-09
7.5	0.0000E+00	0.0000E+00	0.1770E-08	0.6594E-08
12.5	0.0000E+00	0.0000E+00	0.2905E-07	0.2723E-08
17.5	0.0000E+00	0.0000E+00	0.5222E-08	0.8851E-09
22.5	0.0000E+00	0.0000E+00	0.4454E-07	0.1925E-08
27.5	0.0000E+00	0.0000E+00	0.5673E-07	0.8054E-08
35.0	0.9559E-08	0.3879E-07	0.3748E-07	0.4403E-08
45.0	0.6395E-08	0.3865E-07	0.1086E-06	0.8983E-08
55.0	0.6505E-08	0.6047E-07	0.4018E-07	0.9160E-08

Rad(km)	Tot Rad Coll Air Dose	Tot Rad Coll Liq Dose	Tot (Gas and L
2.5	0.7439E-09	0.1011E-07	0.1086E-07
7.5	0.6375E-09	0.2047E-07	0.2110E-07
12.5	0.8983E-09	0.4394E-07	0.4484E-07
17.5	0.2583E-09	0.1629E-07	0.1654E-07
22.5	0.6381E-09	0.4647E-07	0.4710E-07
27.5	0.1601E-08	0.1400E-06	0.1412E-06
35.0	0.2265E-07	0.2088E-05	0.2110E-05
45.0	0.4278E-08	0.4225E-06	0.4268E-06
55.0	0.4115E-08	0.4301E-06	0.4342E-06

Total Collective Air dose : 0.3590E-07 man-Sv/year

Total Collective Liquid dose : 0.3217E-05 man-Sv/year

Total Collective (Air & Liquid dose) : 0.3253E-05 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.4600E-02 Ba/l

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
7.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
12.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
17.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
22.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
27.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
35.0	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
45.0	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
55.0	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
7.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
12.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
17.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
22.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
27.5	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
35.0	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
45.0	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10
55.0	0.2227E-10	0.2227E-10	0.2227E-10	0.2227E-10

Local Air Dose Rates for Nuclide I129 ** Pt.-Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.4620E-05 Fa/s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1015E-15	0.1259E-15	0.0000E+00	0.0000E+00
7.5	0.1499E-15	0.2490E-16	0.0000E+00	0.0000E+00
12.5	0.5345E-16	0.3628E-16	0.0000E+00	0.0000E+00
17.5	0.1100E-16	0.4470E-16	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.2896E-15	0.0000E+00	0.0000E+00
35.0	0.1635E-15	0.6649E-14	0.9839E-17	0.0000E+00
45.0	0.9751E-16	0.7001E-15	0.1859E-16	0.0000E+00
55.0	0.3256E-16	0.8344E-15	0.5021E-16	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.5903E-16
7.5	0.0000E+00	0.0000E+00	0.2110E-16	0.3892E-16
12.5	0.0000E+00	0.0000E+00	0.2165E-15	0.1125E-16
17.5	0.0000E+00	0.0000E+00	0.2919E-16	0.3108E-17
22.5	0.0000E+00	0.0000E+00	0.2058E-15	0.6059E-17
27.5	0.0000E+00	0.0000E+00	0.2291E-15	0.2359E-16
35.0	0.3252E-16	0.1284E-15	0.1327E-15	0.1307E-16
45.0	0.1970E-16	0.1166E-15	0.3452E-15	0.2342E-16
55.0	0.1875E-16	0.1713E-15	0.1188E-15	0.2312E-16

Rad(km)	Tot Rad Coll Dose
2.5	0.2864E-15
7.5	0.2349E-15
12.5	0.3175E-15
17.5	0.8801E-16
22.5	0.2119E-15
27.5	0.5423E-15
35.0	0.7128E-14
45.0	0.1321E-14
55.0	0.1249E-14

Total Collective dose : 0.1170E-13 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.6600E-09 Tot

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1036E-17	0.7073E-18	0.1418E-17	0.1142E-17
7.5	0.3372E-18	0.2412E-18	0.4485E-18	0.3679E-18
12.5	0.1974E-18	0.1480E-18	0.2546E-18	0.2132E-18
17.5	0.1480E-18	0.1151E-18	0.1862E-18	0.1586E-18
22.5	0.1192E-18	0.9595E-19	0.1463E-18	0.1267E-18
27.5	0.1020E-18	0.8443E-19	0.1223E-18	0.1076E-18
35.0	0.8717E-19	0.7456E-19	0.1018E-18	0.9123E-19
45.0	0.7648E-19	0.6744E-19	0.8698E-19	0.7939E-19
55.0	0.6990E-19	0.6305E-19	0.7705E-19	0.7214E-19

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.7073E-18	0.6546E-18	0.7862E-18	0.7357E-18
7.5	0.2412E-18	0.2259E-18	0.2643E-18	0.1999E-18
12.5	0.1480E-18	0.1401E-18	0.1599E-18	0.9079E-19
17.5	0.1151E-18	0.1099E-18	0.1230E-18	0.7698E-19
22.5	0.9595E-19	0.9222E-19	0.1015E-18	0.6892E-19
27.5	0.8443E-19	0.8163E-19	0.8864E-19	0.6408E-19
35.0	0.7456E-19	0.7255E-19	0.7759E-19	0.5924E-19
45.0	0.6744E-19	0.6599E-19	0.6961E-19	0.5684E-19
55.0	0.6305E-19	0.6195E-19	0.6449E-19	0.5510E-19

Local Air Dose Rates for Nuclide nbgs ** Pt.-Leprea

** Coll equiv dose rate (man-Sv/year) ** Source in air : 0.2540E-0[illegible] Sv-y

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.5476E-06	0.6873E-06	0.0000E+00	0.0000E+00
7.5	0.7500E-06	0.1160E-06	0.0000E+00	0.0000E+00
12.5	0.2346E-06	0.1413E-06	0.0000E+00	0.0000E+00
17.5	0.4284E-07	0.1490E-06	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.7003E-06	0.0000E+00	0.0000E+00
35.0	0.4109E-06	0.1307E-04	0.2955E-07	0.0000E+00
45.0	0.2012E-06	0.1091E-05	0.4682E-07	0.0000E+00
55.0	0.5562E-07	0.1052E-05	0.1049E-06	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.2935E-06
7.5	0.0000E+00	0.0000E+00	0.1009E-06	0.1409E-06
12.5	0.0000E+00	0.0000E+00	0.8750E-06	0.2992E-07
17.5	0.0000E+00	0.0000E+00	0.1021E-06	0.6476E-08
22.5	0.0000E+00	0.0000E+00	0.6166E-06	0.9993E-08
27.5	0.0000E+00	0.0000E+00	0.5913E-06	0.3148E-07
35.0	0.6394E-07	0.2387E-06	0.2008E-06	0.1237E-07
45.0	0.3069E-07	0.1707E-06	0.5836E-06	0.1811E-07
55.0	0.2365E-07	0.2022E-06	0.1636E-06	0.1399E-07

Rad(km)	Tot Rad Coll Dose
2.5	0.1548E-05
7.5	0.1109E-05
12.5	0.1281E-05
17.5	0.3004E-06
22.5	0.6266E-06
27.5	0.1323E-05
35.0	0.1411E-04
45.0	0.2142E-05
55.0	0.1618E-05

Total Collective dose : 0.2406E-04 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in air : 0.3540E+05 Ba-Me./s

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.5704E-08	0.3804E-08	0.7912E-08	0.6314E-08
7.5	0.1664E-08	0.1109E-08	0.2308E-08	0.1842E-08
12.5	0.8559E-09	0.5706E-09	0.1187E-08	0.9472E-09
17.5	0.5706E-09	0.3804E-09	0.7912E-09	0.6314E-09
22.5	0.4042E-09	0.2694E-09	0.5604E-09	0.4473E-09
27.5	0.3043E-09	0.2029E-09	0.4220E-09	0.3368E-09
35.0	0.2187E-09	0.1458E-09	0.3033E-09	0.2421E-09
45.0	0.1569E-09	0.1046E-09	0.2176E-09	0.1736E-09
55.0	0.1189E-09	0.7925E-10	0.1648E-09	0.1316E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.3804E-08	0.3500E-08	0.4040E-08	0.1598E-08
7.5	0.1109E-08	0.1021E-08	0.1243E-08	0.4660E-09
12.5	0.5706E-09	0.5249E-09	0.6391E-09	0.2396E-09
17.5	0.3804E-09	0.3500E-09	0.4260E-09	0.1598E-09
22.5	0.2694E-09	0.2479E-09	0.3018E-09	0.1133E-09
27.5	0.2029E-09	0.1866E-09	0.2272E-09	0.8521E-10
35.0	0.1458E-09	0.1342E-09	0.1633E-09	0.6124E-10
45.0	0.1046E-09	0.9624E-10	0.1172E-09	0.4394E-10
55.0	0.7925E-10	0.7291E-10	0.8876E-10	0.3329E-10

Local Liquid Dose Rates for Nuclide Zn65 ** Pt.-Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.4603E-02 Bq/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1945E-06	0.3533E-06	0.0000E+00	0.0000E+00
7.5	0.8812E-06	0.2044E-06	0.0000E+00	0.0000E+00
12.5	0.5359E-06	0.4843E-06	0.0000E+00	0.0000E+00
17.5	0.1469E-06	0.7661E-06	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.6750E-05	0.0000E+00	0.0000E+00
35.0	0.3691E-05	0.1753E-03	0.1905E-06	0.0000E+00
45.0	0.2507E-05	0.2038E-04	0.4007E-06	0.0000E+00
55.0	0.9149E-06	0.2596E-04	0.1268E-05	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.359[illegible]E-06
7.5	0.0000E+00	0.0000E+00	0.1588E-06	0.591[illegible]E-06
12.5	0.0000E+00	0.0000E+00	0.2677E-05	0.2441E-06
17.5	0.0000E+00	0.0000E+00	0.4484E-06	0.7939E-07
22.5	0.0000E+00	0.0000E+00	0.3995E-05	0.1727E-06
27.5	0.0000E+00	0.0000E+00	0.5089E-05	0.7224E-06
35.0	0.8574E-06	0.3479E-05	0.3362E-05	0.3949E-06
45.0	0.5736E-06	0.3467E-05	0.9741E-05	0.8056E-06
55.0	0.5835E-06	0.5424E-05	0.3604E-05	0.8316E-06

Rad(km)	Tot Rad Coll Dose
2.5	0.9070E-06
7.5	0.1137E-05
12.5	0.3942E-05
17.5	0.1461E-05
22.5	0.4148E-05
27.5	0.1256E-04
35.0	0.1872E-03
45.0	0.3790E-04
55.0	0.3858E-04

Total Collective Liquid dose : 0.2884E-03 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.4600E-01 Bq/L

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
7.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
12.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
17.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
22.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
27.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
35.0	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
45.0	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
55.0	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
7.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
12.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
17.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
22.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
27.5	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
35.0	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
45.0	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08
55.0	0.2030E-08	0.2030E-08	0.2030E-08	0.2030E-08

Local Liquid Dose Rates for Nuclide Zr95 ** Pt.-Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.4600E-02 Ba/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1214E-07	0.2205E-07	0.0000E+00	0.0000E+00
7.5	0.5500E-07	0.1276E-07	0.0000E+00	0.0000E+00
12.5	0.3345E-07	0.3022E-07	0.0000E+00	0.0000E+00
17.5	0.9167E-08	0.4781E-07	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.4213E-06	0.0000E+00	0.0000E+00
35.0	0.2304E-06	0.1094E-04	0.1189E-07	0.0000E+00
45.0	0.1565E-06	0.1272E-05	0.2626E-07	0.0000E+00
55.0	0.5711E-07	0.1621E-05	0.7915E-07	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.2242E-07
7.5	0.0000E+00	0.0000E+00	0.9910E-08	0.3691E-07
12.5	0.0000E+00	0.0000E+00	0.1671E-06	0.1524E-07
17.5	0.0000E+00	0.0000E+00	0.2923E-07	0.4958E-08
22.5	0.0000E+00	0.0000E+00	0.2494E-06	0.1078E-07
27.5	0.0000E+00	0.0000E+00	0.3174E-06	0.4509E-07
35.0	0.5351E-07	0.2171E-06	0.2098E-06	0.2465E-07
45.0	0.3580E-07	0.2164E-06	0.6060E-06	0.5029E-07
55.0	0.3642E-07	0.3385E-06	0.2250E-06	0.5128E-07

Rad(km)	Tot Rad Coll Dose
2.5	0.5661E-07
7.5	0.1144E-06
12.5	0.2460E-06
17.5	0.9117E-07
22.5	0.2601E-06
27.5	0.7840E-06
35.0	0.1169E-04
45.0	0.2365E-05
55.0	0.2408E-05

Total Collective Liquid dose : 0.1801E-04 man Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.4400E-0[illegible]

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
7.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
12.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
17.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
22.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
27.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
35.0	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
45.0	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
55.0	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
7.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
12.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
17.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
22.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
27.5	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
35.0	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
45.0	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09
55.0	0.1272E-09	0.1272E-09	0.1272E-09	0.1272E-09

Local Liquid Dose Rates for Nuclide SrA9 ** Pt.-Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.4605E-02 Pe

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2079E-10	0.3775E-10	0.0000E+00	0.0000E-00
7.5	0.9417E-10	0.2185E-10	0.0000E+00	0.0000E+00
12.5	0.5727E-10	0.5175E-10	0.0000E+00	0.0000E-00
17.5	0.1570E-10	0.8187E-10	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.7214E-09	0.0000E+00	0.0000E+00
35.0	0.3945E-09	0.1873E-07	0.2036E-10	0.0000E+00
45.0	0.2479E-09	0.2179E-08	0.4497E-10	0.0000E+00
55.0	0.9778E-10	0.3775E-00	0.1355E-09	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.3939E-10
7.5	0.0000E+00	0.0000E+00	0.1697E-10	0.6321E-10
12.5	0.0000E+00	0.0000E+00	0.2861E-09	0.2609E-10
17.5	0.0000E+00	0.0000E+00	0.5006E-10	0.8484E-11
22.5	0.0000E+00	0.0000E+00	0.4270E-09	0.1845E-10
27.5	0.0000E+00	0.0000E+00	0.5438E-09	0.7721E-10
35.0	0.9163E-10	0.3718E-09	0.3593E-09	0.4221E-10
45.0	0.6130E-10	0.3705E-09	0.1041E-08	0.8611E-10
55.0	0.6236E-10	0.5797E-09	0.3852E-09	0.8781E-10

Rad(km)	Tot Rad Coll Dose
2.5	0.9493E-10
7.5	0.1940E-09
12.5	0.4212E-09
17.5	0.1561E-09
22.5	0.4454E-09
27.5	0.1342E-08
35.0	0.2001E-07
45.0	0.4050E-08
55.0	0.4123E-08

Total Collective Liquid dose : 0.3081E-07 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.4500E-02 Bq/l

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
7.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
12.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
17.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
22.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
27.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
35.0	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
45.0	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
55.0	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
7.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
12.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
17.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
22.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
27.5	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
35.0	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
45.0	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12
55.0	0.2139E-12	0.2139E-12	0.2139E-12	0.2139E-12

Local Liquid Dose Rates for Nuclide Sr90 ** Pt.-Loorsu

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.4600E-02 Pa/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3155E-09	0.5731E-09	0.0000E+00	0.0000E+00
7.5	0.1430E-08	0.3316E-09	0.0000E+00	0.0000E+00
12.5	0.8693E-09	0.7856E-09	0.0000E+00	0.0000E+00
17.5	0.2383E-09	0.1243E-08	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.1095E-07	0.0000E+00	0.0000E+00
35.0	0.5989E-06	0.2843E-06	0.3091E-09	0.0000E+00
45.0	0.4066E-08	0.3307E-07	0.6826E-09	0.0000E+00
55.0	0.1484E-08	0.4212E-07	0.2057E-08	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.5020E-09
7.5	0.0000E+00	0.0000E+00	0.2576E-09	0.9595E-09
12.5	0.0000E+00	0.0000E+00	0.4343E-08	0.3960E-09
17.5	0.0000E+00	0.0000E+00	0.7598E-09	0.1298E-09
22.5	0.0000E+00	0.0000E+00	0.6481E-08	0.2801E-09
27.5	0.0000E+00	0.0000E+00	0.8255E-08	0.1172E-08
35.0	0.1391E-08	0.5644E-08	0.5454E-08	0.6407E-09
45.0	0.9305E-09	0.5625E-08	0.1580E-07	0.1307E-08
55.0	0.9466E-09	0.8799E-08	0.5847E-08	0.1333E-08

Rad(km)	Tot Rad Coll Dose
2.5	0.1471E-08
7.5	0.2978E-08
12.5	0.6394E-08
17.5	0.2370E-08
22.5	0.6761E-08
27.5	0.2039E-07
35.0	0.3038E-06
45.0	0.6148E-07
55.0	0.6259E-07

Total Collective Liquid dose : 0.4682E-06 man-Sv/year

** Indv Equiv dose rate (Sv/ymar) ** Source in water : 0.4600E-02 Bq/L

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
7.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
12.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
17.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
22.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
27.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
35.0	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
45.0	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
55.0	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
7.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
12.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
17.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
22.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
27.5	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
35.0	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
45.0	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11
55.0	0.3120E-11	0.3120E-11	0.3120E-11	0.3120E-11

Local Liquid Dose Rates for Nuclide Co60 ** Pt.-Leprea

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.4500E-02 Sv/

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.6076E-07	0.1104E-06	0.0000E+00	0.0000E+00
7.5	0.2753E-06	0.6386E-07	0.0000E+00	0.0000E+00
12.5	0.1674E-06	0.1513E-06	0.0000E+00	0.0000E+00
17.5	0.4588E-07	0.2393E-06	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.2109E-05	0.0000E+00	0.0000E+00
35.0	0.1153E-05	0.5475E-04	0.5952E-07	0.0000E+00
45.0	0.7830E-06	0.6368E-05	0.1314E-06	0.0000E+00
55.0	0.2858E-06	0.8110E-05	0.3962E-06	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.1122E-06
7.5	0.0000E+00	0.0000E+00	0.4960E-07	0.1848E-06
12.5	0.0000E+00	0.0000E+00	0.8367E-06	0.7626E-07
17.5	0.0000E+00	0.0000E+00	0.1463E-06	0.2480E-07
22.5	0.0000E+00	0.0000E+00	0.1248E-05	0.5394E-07
27.5	0.0000E+00	0.0000E+00	0.1590E-05	0.2257E-06
35.0	0.2678E-06	0.1007E-05	0.1050E-05	0.1274E-06
45.0	0.1792E-06	0.1083E-05	0.3043E-05	0.2517E-06
55.0	0.1823E-06	0.1694E-05	0.1126E-05	0.2567E-06

Rad(km)	Tot Rad Coll Dose
2.5	0.2833E-06
7.5	0.5735E-06
12.5	0.1231E-05
17.5	0.4563E-06
22.5	0.1302E-05
27.5	0.3924E-05
35.0	0.5849E-04
45.0	0.1194E-04
55.0	0.1205E-04

Total Collective Liquid dose : 0.9015E-04 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.4600E-02 Bq/L

	Sector (clockwise from N)			
Rad(km)	1	2	3	4
2.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
7.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
12.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
17.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
22.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
27.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
35.0	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
45.0	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
55.0	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09

	Sector (clockwise from N)			
Rad(km)	5	6	7	8
2.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
7.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
12.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
17.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
22.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
27.5	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
35.0	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
45.0	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09
55.0	0.6350E-09	0.6350E-09	0.6350E-09	0.6350E-09

Local Liquid Dose Rates for Nuclide Fe59 ** Pt. Lepreau

** Coll equiv dose rate (man-Sv/year) ** Source in water : 0.4600E-02 Bq

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.4799E-07	0.8717E-07	0.0000E+00	0.0000E+00
7.5	0.2174E-06	0.5044E-07	0.0000E+00	0.0000E+00
12.5	0.1322E-06	0.1195E-06	0.0000E+00	0.0000E+00
17.5	0.3624E-07	0.1890E-06	0.0000E+00	0.0000E+00
22.5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27.5	0.0000E+00	0.1665E-05	0.0000E+00	0.0000E+00
35.0	0.9108E-06	0.4325E-04	0.4701E-07	0.0000E+00
45.0	0.6185E-06	0.5030E-05	0.1038E-06	0.0000E+00
55.0	0.2258E-06	0.6406E-05	0.3129E-06	0.0000E+00

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.0000E+00	0.0000E+00	0.0000E+00	0.8864E-07
7.5	0.0000E+00	0.0000E+00	0.3918E-07	0.1459E-06
12.5	0.0000E+00	0.0000E+00	0.6606E-06	0.6023E-07
17.5	0.0000E+00	0.0000E+00	0.1156E-06	0.1959E-07
22.5	0.0000E+00	0.0000E+00	0.9858E-06	0.4260E-07
27.5	0.0000E+00	0.0000E+00	0.1256E-05	0.1783E-06
35.0	0.2116E-06	0.8584E-06	0.8296E-06	0.9745E-07
45.0	0.1415E-06	0.8555E-06	0.2403E-05	0.1938E-06
55.0	0.1440E-06	0.1338E-05	0.8393E-06	0.3027E-06

Rad(km)	Tot Rad Coll Dose
2.5	0.2238E-06
7.5	0.4530E-06
12.5	0.9725E-06
17.5	0.3604E-06
22.5	0.1028E-05
27.5	0.3099E-05
35.0	0.4620E-04
45.0	0.9351E-05
55.0	0.9519E-05

Total Collective Liquid dose : 0.7121E-04 man-Sv/year

** Indv Equiv dose rate (Sv/year) ** Source in water : 0.4600E-02 Bq/L

Rad(km)	Sector (clockwise from N) 1	2	3	4
2.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
7.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
12.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
17.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
22.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
27.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
35.0	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
45.0	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
55.0	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09

Rad(km)	Sector (clockwise from N) 5	6	7	8
2.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
7.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
12.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
17.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
22.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
27.5	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
35.0	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
45.0	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09
55.0	0.5010E-09	0.5010E-09	0.5010E-09	0.5010E-09

Table D.6 - Program Listing for CLDOSL

```
      PROGRAM CLDOSL
C
C ================================================================
C   This program calculates the collective population dose rate
C for the local population (< 100 km) in the vicinity of a nuclear
C facility using the steady-state compartment model of Ontario
C Hydro.
C
C   The annual dose rate for individuals is calculated as a function
C of x and theta and the angular distribution is integrated to also
C give the collective annual dose rate as a function of the radial
C displacement only.
C
C   Note the individual dose rates output are the ADULT values only.
C The collective dose rates are weighted for both adults and infants.
C
C   Wherever possible the default values for the transfer parameters
C P(mn) are used. For each nuclide of interest the parameters are
C stored in the table <Nuc>.<Site>.loc . The  parameters P(01)
C (assuming isotropic wind rose), the wind rose, the population
C data, the site dependent parameters for determining P(02), and the
C assumed source(s) of foodstuffs for each site are in the file
C <Site>.loc .
C
C   The dose rates are EFFECTIVE dose rates.
C ================================================================
C
      DIMENSION PT(49), XRAD(15), IPOP(15,8), WIND(8),P01(15)
      DIMENSION DOSA(15,8), DOSW(15,8), CLDOSAR(15)
      CHARACTER SITE*4, SITAB*8, SITNAME*24, NUCLID*6, NUCFILE*15
      CHARACTER*10 OUTPUT
      CHARACTER FFEED
      LOGICAL SITCHK
C
C  Input Site name - Max 4 char code
C        darl ==> Darlington
C        ptlp ==> Pt. Lepreau
C
10    WRITE(6,2000)
      READ(5,1000,ERR=10) SITE
      SITAB = SITE // '.loc'
      INQUIRE (FILE=SITAB,EXIST=SITCHK)
      IF (SITCHK) THEN
        GOTO 20
      ELSE
        WRITE(6,2010) SITAB
        GOTO 10
      ENDIF
C
C  Read in Site specific parameters from file SITAB.loc
C
20    CALL RDSITE(SITAB,SITNAME,NRAD,XRAD,NSECT,WIND,IPOP,P01,
     1            P01F,NSECTF,P02,POPINF,IFLAG)
      IF (IFLAG .NE. 0) GOTO 900
C
C Open output file
C
      OUTPUT = 'cldosl.dat'
      OPEN(UNIT=22,FILE=OUTPUT)
C
C  Define form feed
C
      FFEED = CHAR(12)
C
```

```
C  Input nuclide file name
C
30     NUCLID = '      '
       WRITE(6,2020) SITAB
33     READ(5,1001,ERR=35) NUCLID
       GOTO 40
C Input error
35     WRITE(6,2025)
       GOTO 33
C
40     IF(NUCLID(1:1).EQ. ' ') GOTO 800
       IN = INDEX(NUCLID,' ')
       IF (IN.EQ.0) THEN
         NUCFILE = NUCLID // '.' // SITAB
C        OUTPUT = NUCLID // '.dat'
       ELSE
         NUCFILE = NUCLID(1:IN-1) // '.' // SITAB
C        OUTPUT = NUCLID(1:IN-1) // '.dat'
       ENDIF
C
C Read in nuclide transfer parameters
C
       CALL RDNUC(NUCFILE, PT, EMAIR, EMWAT, IFLAG)
       IF (IFLAG .NE. 0) GOTO 900
C
C Calculate air equivalent dose
C
       IF (EMAIR.NE.0) THEN
         WRITE(22,2100) FFEED
         CALL AIRDOS(NRAD,XRAD,NSECT,WIND,IPOP,P01,P01F,NSECTF,PT,
     1               EMAIR,NUCLID,POPINF,SITNAME,CLDOSAR)
       ENDIF
C
C Calculate water equivalent dose
C
       IF(EMWAT.NE.0) THEN
         WRITE(22,2100) FFEED
         IF (SITE.EQ.'ptlp') THEN
C Pt. Lepreau
           CALL WATDOSLP(NRAD,XRAD,NSECT,IPOP,P02,PT,EMWAT,NUCLID,EMAIR,
     1               POPINF,SITNAME,CLDOSAR)
         ELSE
C Darlington
           CALL WATDOSDL(NRAD,XRAD,NSECT,IPOP,P02,PT,EMWAT,NUCLID,EMAIR,
     1               POPINF,SITNAME,CLDOSAR)
         ENDIF
       ENDIF
C
C Back to top for next nuclide
C
       GOTO 30
C
C Close Output file
C
800    CLOSE(UNIT=22)
       STOP
C
900    STOP 'ERROR IN DATA INPUT'
C
C   Format Statements
C
1000   FORMAT(A4)
1001   FORMAT(A5)
2000   FORMAT(/' Enter site code (4 characters): ')
2010   FORMAT(/' *** File ',A8,' does not exist - Renter code ***')
2020   FORMAT(/' Enter nuclide code (5 char)(.',A8,' is assumed): ')
```

```
2025  FORMAT(/' *** Input error - Reenter nuclide code (5 char)! ')
2100  FORMAT(' ',A1)
C
      END
C
C
      SUBROUTINE RDSITE(SITAB,SITNAME,NRAD,XRAD,NSECT,WIND,IPOP,P01,
     1         P01F,NSECTF,P02,POPINF,IFLAG)
C
C  Routine to read in site specific parameters from the file SITAB.loc
C
      CHARACTER*8 SITAB
      CHARACTER SITNAME*24
      CHARACTER SITE*4
      DIMENSION XRAD(15), WIND(8), IPOP(15,8), P01(15)
C
C  Open data file
C
      IFLAG = 0
      OPEN (UNIT=11,FILE=SITAB,STATUS='OLD',ERR=500)
C
C Read Site name in full
      READ(11,1000) SITNAME
C Read # of radial pts., values in km  (12 xrad values /line)
      READ(11,1010) NRAD, (XRAD(K),K=1,NRAD)
C Read # of wind sectors, values (%) N to NW clockwise
      READ(11,1020) NSECT, (WIND(K),K=1,NSECT)
C Read population data for each sector by radial positions
      READ(11,1030)
      DO 30 I=1,NSECT
30    READ(11,1035)(IPOP(K,I),K=1,NRAD)
C
C Population data for Pt. Lepreau is for 1981. To correct for 1988
C values assume 1% increase per year for N.B.
      POPGROW = 1.072
C Get site code
      SITE = SITAB(1:4)
      IF (SITE .EQ. 'ptlp') THEN
        DO 34 K=1,NRAD
        DO 34 I=1,NSECT
34      IPOP(K,I) = IPOP(K,I) * POPGROW + 0.5
      ENDIF
C
C Read fraction of population that are infants (<2 yrs)
C
      READ(11,1095) POPINF
C
C Read atmos. dilution parameters P(01) for each radius (assume uniform wind)
      READ(11,1040) (P01(K),K=1,NRAD)
C Read value of P(01) for sector producing land_based produce, sector #
      READ(11,1050) P01F, NSECTF
C Read value of P(02) - Assume average dilution factor for entire area
C Note this value is just the dilution factor Df. The conversion from
C Bq/s to Bq/L is already included in the source emission rate (Bq/L)
      READ(11,1070) P02
C
      CLOSE(UNIT=11)
      RETURN
C
500   WRITE(6,2000) SITAB
      IFLAG = 1
      RETURN
C
1000  FORMAT(////A24)
1010  FORMAT(//I2,12(F5.1))
1020  FORMAT(//I2,8(F5.1))
```

```
1030  FORMAT(//)
1035  FORMAT(10I8)
1040  FORMAT(//10F8.1)
1050  FORMAT(//F8.1,I2)
1070  FORMAT(////E8.1)
1095  FORMAT(//F5.1)
2000  FORMAT(/'** Error opening ',A8,' **'/)
      END
C
C
      SUBROUTINE RDNUC(NUCFILE, PT, EMAIR, EMWAT, IFLAG)
C
      DIMENSION PT(1)
      CHARACTER NUCFILE*15
      IFLAG = 0
C Read Transfer parameters
      OPEN (UNIT=11, FILE=NUCFILE, STATUS='OLD', ERR=900)
C
C Read air & water emission rates (Bq/sec for air),(Bq/L for water)
      READ(11,1100) EMAIR, EMWAT
C
C  The transfer parameters are stored in the following order:
C
C  P(i)19adult   P(i)19infant  P(e)19        P(13)          P(14)forage
C  P(14)crops    P(15)milk     P(15)beef     P(15)pork      P(15)eggs
C  P(15)chicken  P(34)forage   P(34)crops    P(45)milk      P(45)beef
C  P(45)pork     P(45)eggs     P(45)chicken  P(39)          P(49)adult
C  P(49)infant   P(59)milk(ad) P(59)milk(in) P(59)bf(ad)    P(59)bf(inf)
C  P(59)prk(ad)  P(59)prk(inf) P(59)eggs(ad) P(59)eggs(inf) P(59)chk(ad)
C  P(59)chk(inf) P(26)frfsh    P(26)ocfsh    P(26)crst,mol  P(27)
C  P(28)         P(69)frfs(a)  P(69)ocfs(a)  P(69)crst,mol(a) P(79)(ad)
C  P(89)         Rd(02)decay   P(i)29ad      P(i)29inf      P(e)29
C  P(69)frfsh(in) P(69)ocfsh(in) P(69)crst,mol(in)  P(79)inf
C
C Note: For Pt. LePreau , Rd=PT(42)= EXP(- Lambda*T)
C       For Darlington, Lambda = PT(42) and Rd must be calculated
C       This is due to the fact that ther are sveral different sites
C       along the lake (different T values) that are used in the
C       calculation.
      NTRAN = 49
C
      READ(11,1010)
      DO 10 K=1,NTRAN
10    READ(11,1000) PT(K)
C
      CLOSE (UNIT=11)
      RETURN
C
900   WRITE(6,2000) NUCFILE
      IFLAG = 1
      RETURN
C
1000  FORMAT(F8.1)
1010  FORMAT(/)
1100  FORMAT(//2F8.1)
2000  FORMAT(/' ** Error reading file ',A15,' **'/)
      END
C
C
      SUBROUTINE AIRDOS(NRAD,XRAD,NSECT,WIND,IPOP,P01,P01F,NSECTF,
     1                  PT,EMAIR,NUCLID,POPINF,SITNAME,CLDOSAR)
C
C  This routine calculates individual dose rates for air sources
C  The total collective for all sectors is also calculated
C
      DIMENSION XRAD(1),WIND(1),IPOP(15,8),P01(1),PT(1),DOSA(15,8)
```

```
      DIMENSION CLDOSA(8),CLDOSAR(1),DOSI(15,8)
      CHARACTER*9 UNIT
      CHARACTER*6 NUCLID
      CHARACTER*24 SITNAME
C
      CLDOSAT = 0
      WRITE(22,2200) NUCLID, SITNAME
C  Units Bq-Mev/s for noble gases source
      IF (NUCLID(1:4).EQ.'nbgs') THEN
        UNIT = ' Bq-Mev/s'
      ELSE
        UNIT = ' Bq/s     '
      ENDIF
      WRITE(22,1150) EMAIR, UNIT
C
C  Calc for adults & infants
      POPADLT = 1.0 - POPINF
C
C Correct P01F (food source) for wind rose
      J1 = NSECTF+NSECT/2
      IF(NSECTF.GT.8) J1=MOD(J1,NSECT)
      P01FC = P01F * (WIND(J1)/100.)
C
C Get individual dose/unit source for foodstuffs
C Note value of P01F is used for part of calc in food chain (NOT P01C)
C
C Vegetables  - Adults
      DOS2 = PT(4)*PT(13)*PT(20) + PT(6)*PT(20)
C Vegetables - infants
      DOS2I = PT(4)*PT(13)*PT(21) + PT(6)*PT(21)
C Animal Produce!
C PTAN459 is weighted effect of P45*P49 for animal produce
C PTAN159 is weighted effect P15*P59
C Adults
      PTAN459 = PT(14)*PT(22) + PT(15)*PT(24) + PT(16)*PT(26) +
     1          PT(17)*PT(28) + PT(18)*PT(30)
C
      PTAN159 = PT(7)*PT(22) + PT(8)*PT(24) + PT(9)*PT(26) +
     1          PT(10)*PT(28) + PT(11)*PT(30)
C
      DOS2 = DOS2 + PTAN159 +
     1       PT(5)*PTAN459 + PT(4)*PT(12)*PTAN459
C
      DOS2 = DOS2 * P01FC
C
C Infants
      PTAN459I = PT(14)*PT(23) + PT(15)*PT(25) + PT(16)*PT(27) +
     1           PT(17)*PT(29) + PT(18)*PT(31)
C
      PTAN159I = PT(7)*PT(23) + PT(8)*PT(25) + PT(16)*PT(27) +
     1           PT(10)*PT(29) + PT(11)*PT(31)
C
      DOS2I = DOS2I + PTAN159I +
     1       PT(5)*PTAN459I + PT(4)*PT(12)*PTAN459I
C
      DOS2I = DOS2I * P01FC
C
C Calculate dose for each sector
      KMAX = NSECT/4
C  Do 4 sectors at a time ( for output)
      DO 10 K = 1,KMAX
      J1 = 4*K-3
      J2 = 4*K
      WRITE(22,1200) (KK,KK=J1,J2)
C
C Radial distance
```

```
      DO 10 I =1,NRAD
      IF(K.EQ.1) CLDOSAR(I) = 0.
C
C Angular sector
      DO 20 J = J1,J2
C
C  Correct P01 for Wind rose ! Note that wind blows into sector j for
C  values in table (correction is below).
      JR = J+NSECT/2
      IF(JR.GT.NSECT) JR = MOD(JR,NSECT)
C
      P01C = P01(I) * (WIND(JR)/100.) * NSECT
C
C  Individual dose rate/ unit source (not food related)
C Adults
      DOS1 = P01C * ( PT(1) + PT(3) + PT(4)*PT(19) )
C Infants ( Note P(e)19_inf = P(e)19_ad * 1.5 )
      DOS1I = P01C * ( PT(2) + PT(3)*1.5 + PT(4)*PT(19) )
C
C  Total individual equivalent dose rate for sector (I,J)
      DOSA(I,J) = EMAIR * (DOS1 + DOS2)
      DOSI(I,J) = EMAIR * (DOS1I + DOS2I)
C  Collective dose for sector (I,J)
      CLDOSA(J) = DOSA(I,J) * IPOP(I,J) * POPADLT  +
     1            DOSI(I,J) * IPOP(I,J) * POPINF
C  Total radial collective dose
      CLDOSAR(I) = CLDOSAR(I) + CLDOSA(J)
20    CONTINUE
C
C  Output dose rates for radius I
C
      WRITE(22,1100) XRAD(I),(CLDOSA(J),J=4*K-3,4*K)
10    CONTINUE
C
C Output total collective dose for each radius
      WRITE(22,1250)
      DO 30 I =1,NRAD
      WRITE(22,1300) XRAD(I),CLDOSAR(I)
      CLDOSAT = CLDOSAT + CLDOSAR(I)
30    CONTINUE
C Total collective air dose
      WRITE(22,1120) CLDOSAT
C
C  Output individual dose rates by sector (Sv/year)
      WRITE(22,1400) EMAIR, UNIT
      DO 40 K=1,NSECT/4
      J1 = 4*K - 3
      J2 = 4*K
      WRITE(22,1200) (KK,KK=J1,J2)
C
      DO 40 I=1,NRAD
      WRITE(22,1100) XRAD(I),(DOSA(I,J),J=J1,J2)
40    CONTINUE
C
      RETURN
C
1100  FORMAT(/F5.1,4X,4E14.4)
1120  FORMAT(/' Total Collective dose ! ',E14.4,'  man-Sv/year')
1150  FORMAT(/' ** Coll equiv dose rate (man-Sv/year) **',2X,
     1  'Source in air ! ',E12.4,A9)
1400  FORMAT(////' ** Indv Equiv dose rate (Sv/year) **',2X,
     1  'Source in air ! ',E12.4,A9)
1200  FORMAT(//25X,'Sector (clockwise from N)',/2X,'Rad(km)',7X,
     1       4(I2,12X))
1250  FORMAT(//2X,'Rad(km)',4X,'Tot Rad Coll Dose')
1300  FORMAT(2X,F5.1,8X,E12.4)
```

```
2200  FORMAT(8X,'     Local Air Dose Rates for Nuclide ',A6,
     1       '** ',A24/
     1       8X,'     ------------------------------------'//)
      END
C
C
      SUBROUTINE WATDOSLP(NRAD,XRAD,NSECT,IPOP,P02,PT,EMWAT,NUCLID,
     1                    EMAIR,POPINF,SITNAME,CLDOSAR)
C  This routine calculates individual dose rates for water sources
C  for Pt. LePreau
C
C  The total collective for all sectors is also calculated
C
      DIMENSION XRAD(15),IPOP(15,8),PT(1),DOSA(15,8)
      DIMENSION CLDOSA(8),CLDOSLR(15),DOSI(15,8),CLDOSAR(15)
      CHARACTER*24 SITNAME
      CHARACTER NUCLID*6
C
C Zero totals
      CLDOSAT = 0
      CLDOSLT = 0
      CLDOST = 0
      WRITE(22,2200) NUCLID, SITNAME
      WRITE(22,1150) EMWAT
C
C  Calc for adults & infants
C Fraction of pop. adults
      POPADLT = 1.0 - POPINF
C
C Seafood:
C PTAN269 is weighted effect of P26*P69 for seafood
C Adults
      PTAN269 = PT(32)*PT(37) + PT(33)*PT(38) + PT(34)*PT(39)
C Infants
      PTAN269I = PT(32)*PT(46) + PT(33)*PT(47) + PT(34)*PT(48)
C
C Add effect of dulse(pt LPr only) and seafood
C Adults
      DOS2 = PT(35)*PT(48) + PTAN269
C Infants
      DOS2I = PT(35)*PT(49) + PTAN269I
C Multiply P02 by decay factor Rd=exp(-lambda*T)=PT(42)
      DOS2 = DOS2 * P02 * PT(42)
      DOS2I = DOS2I * P02 * PT(42)
C
C Calculate dose for each sector
      KMAX = NSECT/4
C  Do 4 sectors at a time ( for output)
      DO 10 K = 1,KMAX
      J1 = 4*K-3
      J2 = 4*K
      WRITE(22,1200) (KK,KK=J1,J2)
C
C Radial distance
      DO 10 I =1,NRAD
      IF(K.EQ.1) CLDOSLR(I) = 0.
C
C Angular sector
      DO 20 J = J1,J2
C
C  Individual dose rate/ unit source (not food related)
C  Adults
      DOS1 = P02 * PT(42) * ( PT(43) + PT(45) + PT(36)*PT(41) )
C Infants
      DOS1I = P02 * PT(42) * ( PT(44) + PT(45) + PT(36)*PT(41) )
C
```

```
C  Total individual equivalent dose rate for sector (I,J)
      DOSA(I,J) = EMWAT * (DOS1 + DOS2)
      DOSI(I,J) = EMWAT * (DOS1I + DOS2I)
C  Collective dose for sector (I,J)
      CLDOSA(J) = DOSA(I,J) * IPOP(I,J) * POPADLT +
     1            DOSI(I,J) * IPOP(I,J) * POPINF
C  Total radial collective dose
      CLDOSLR(I) = CLDOSLR(I) + CLDOSA(J)
20    CONTINUE
C
C  Output dose rates for radius I
C
      WRITE(22,1100) XRAD(I),(CLDOSA(J),J=4*K-3,4*K)
10    CONTINUE
C
C Output total collective liquid dose for each radius
      IF( EMAIR.EQ.0) THEN
       WRITE(22,1250)
       DO 30 I =1,NRAD
       WRITE(22,1300) XRAD(I),CLDOSLR(I)
       CLDOSLT = CLDOSLT + CLDOSLR(I)
30     CONTINUE
C Total collective liquid dose
       WRITE(22,1120) CLDOSLT
      ELSE
C Output combined air,water radial totals
       WRITE(22,1260)
       DO 35 I =1,NRAD
       CLRTOT = CLDOSAR(I) + CLDOSLR(I)
       WRITE(22,1305) XRAD(I),CLDOSAR(I),CLDOSLR(I),CLRTOT
       CLDOSAT = CLDOSAT + CLDOSAR(I)
       CLDOSLT = CLDOSLT + CLDOSLR(I)
35     CONTINUE
C Total collective dose totals
       CLDOST = CLDOSAT + CLDOSLT
       WRITE(22,1125) CLDOSAT
       WRITE(22,1120) CLDOSLT
C Output combined air,water radial totals
       WRITE(22,1127) CLDOST
      ENDIF
C
C  Output individual dose rates by sector (Sv/year)
      WRITE(22,1400) EMWAT
      DO 40 K=1,NSECT/4
      J1 = 4*K - 3
      J2 = 4*K
      WRITE(22,1200) (KK,KK=J1,J2)
C
      DO 40 I=1,NRAD
      WRITE(22,1100) XRAD(I),(DOSA(I,J),J=J1,J2)
40    CONTINUE
C
      RETURN
C
1100  FORMAT(/F5.1,4X,4E14.4)
1120  FORMAT(/' Total Collective Liquid dose : ',E14.4,'  man-Sv/year')
1125  FORMAT(/' Total Collective Air dose : ',E14.4,'  man-Sv/year')
1127  FORMAT(/' Total Collective (Air & Liquid dose) : ',E14.4,
     1        '  man-Sv/year')
1150  FORMAT(/' ** Coll equiv dose rate (man-Sv/year) **',2X,
     1  'Source in water : ',E12.4,' Bq/L')
1400  FORMAT(////' ** Indv Equiv dose rate (Sv/year) **',2X,
     1  'Source in water : ',E12.4,' Bq/L')
1200  FORMAT(//25X,'Sector (clockwise from N)',/2X,'Rad(km)',7X,
     1       4(I2,12X))
1250  FORMAT(//2X,'Rad(km)',4X,'Tot Rad Coll Dose')
```

```
1260  FORMAT(//2X,'Rad(km)',4X,'Tot Rad Coll Air Dose',4x,
     1       'Tot Rad Coll Liq Dose',4X,
     2       'Tot (Gas and Liq dose)')
1300  FORMAT(2X,F5.1,8X,E12.4)
1305  FORMAT(2X,F5.1,3(10X,E12.4))
2200  FORMAT(8X,'     Local Liquid Dose Rates for Nuclide ',A6,
     1       '** ',A24/
     1       8X,'     ----------------------------------------'//)
      END
C
C
      SUBROUTINE WATDOSDL(NRAD,XRAD,NSECT,IPOP,P02,PT,EMWAT,NUCLID,
     1                    EMAIR,POPINF,SITNAME,CLDOSAR)
C  This routine calculates individual dose rates for water sources
C  for Darlington
C
C  The total collective for all sectors is also calculated
C
      DIMENSION XRAD(15),IPOP(15,8),PT(1),DOSA(15,8)
      DIMENSION CLDOSA(8),CLDOSAR(15),CLDOSLR(15),DOSI(15,8)
      CHARACTER*24 SITNAME
      CHARACTER NUCLID*6
C
C Total collective doses
      CLDOSAT = 0
      CLDOSLT = 0
      CLDOST = 0
C
      WRITE(22,2200) NUCLID, SITNAME
      WRITE(22,1150) EMWAT
C
C  Calc for adults & infants
C Fraction of pop. adults
      POPADLT = 1.0 - POPINF
C
C Seafood:
C PTAN269 is weighted effect of P26*P69 for seafood
C Adults
      PTAN269 = PT(32)*PT(37) + PT(33)*PT(38) + PT(34)*PT(39)
C Infants
      PTAN269I = PT(32)*PT(46) + PT(33)*PT(47) + PT(34)*PT(48)
C
C Add effect of dulse(pt LPr only) and seafood
C Adults
      DOS2 = PT(35)*PT(40) + PTAN269
C Infants
      DOS2I = PT(35)*PT(49) + PTAN269I
C Multiply P02 by decay factor Rd=exp(-lambda*T)
C where lambda = PT(42)
      TFD = 8.8
      RD = EXP(- PT(42)*TFD)
      DOS2 = DOS2 * P02 * RD
      DOS2I = DOS2I * P02 * RD
C
C Calculate dose for each sector
      KMAX = NSECT/4
C  Do 4 sectors at a time ( for output)
      DO 10 K = 1,KMAX
      J1 = 4*K-3
      J2 = 4*K
      WRITE(22,1200) (KK,KK=J1,J2)
C
C Radial distance
      DO 10 I =1,NRAD
      IF(K.EQ.1) CLDOSLR(I) = 0.
C
```

```
C Angular sector
      DO 20 J = J1,J2
C
C  Individual dose rate/ unit source (not food related)
C
C  Swimming and exposure to sediments
C  Site 4.5 Km West of plant
      TSW = 4.1E4
      RDW = EXP(-PT(42)*TSW)
C  Adults & Infants
      DOS1 = P02 * RDW * ( PT(45) + PT(36)*PT(41) )
C
C  Drinking water
C  Two sources: 1) Bomanville
      TDWB = 4.1E4
      RDB = EXP(-PT(42)*TDWB)
C                2) Oshawa region
      TDWO = 1.82E5
      RDO = EXP(-PT(42)*TDWO)
C
      IF( ((I.EQ.1.OR.I.EQ.2) .AND. (J.EQ.1.OR.J.EQ.2))
     1    .OR. (I.EQ.3.AND.J.EQ.1) )  THEN
C Bowmanville - Newcastle
C Adult
        DOS3 = P02 * RDB * PT(43)
C Infant
        DOS3I = P02 * RDB * PT(44)
      ELSE IF( (I.EQ.2.OR.I.EQ.3.OR.I.EQ.4) .AND.
     1         (J.EQ.7.OR.J.EQ.8) ) THEN
C Oshawa region
C Adult
        DOS3 = P02 * RDO * PT(43)
C Infant
        DOS3I = P02 * RDO * PT(44)
      ELSE
        DOS3 = 0.
        DOS3I = 0.
      ENDIF
C
C  Total individual equivalent dose rate for sector (I,J)
      DOSA(I,J) = EMWAT * (DOS1 + DOS2 + DOS3)
      DOSI(I,J) = EMWAT * (DOS1 + DOS2I + DOS3I)
C  Collective dose for sector (I,J)
      CLDOSA(J) = DOSA(I,J) * IPOP(I,J) * POPADLT +
     1            DOSI(I,J) * IPOP(I,J) * POPINF
C  Total radial collective dose
      CLDOSLR(I) = CLDOSLR(I) + CLDOSA(J)
20    CONTINUE
C
C  Output dose rates for radius I
C
      WRITE(22,1100) XRAD(I),(CLDOSA(J),J=J1,J2,4*K)
10    CONTINUE
C
C Output total collective liquid dose for each radius
      IF( EMAIR.EQ.0) THEN
       WRITE(22,1250)
       DO 30 I =1,NRAD
       WRITE(22,1300) XRAD(I),CLDOSLR(I)
       CLDOSLT = CLDOSLT + CLDOSLR(I)
30     CONTINUE
C Total collective liquid dose
       WRITE(22,1120) CLDOSLT
      ELSE
C Output combined air,water radial totals
       WRITE(22,1260)
```

```
      DO 35 I =1,NRAD
      CLRTOT = CLDOSAR(I) + CLDOSLR(I)
      WRITE(22,1305) XRAD(I),CLDOSAR(I),CLDOSLR(I),CLRTOT
      CLDOSAT = CLDOSAT + CLDOSAR(I)
      CLDOSLT = CLDOSLT + CLDOSLR(I)
35    CONTINUE
C Total collective dose totals
      WRITE(22,1125) CLDOSAT
      WRITE(22,1120) CLDOSLT
C Output combined air,water radial totals
      CLDOST = CLDOSAT + CLDOSLT
      WRITE(22,1127) CLDOST
     ENDIF
C
C  Output individual dose rates by sector (Sv/year)
      WRITE(22,1400) EMWAT
      DO 40 K=1,NSECT/4
      J1 = 4*K - 3
      J2 = 4*K
      WRITE(22,1200) (KK,KK=J1,J2)
C
      DO 40 I=1,NRAD
      WRITE(22,1100) XRAD(I),(DOSA(I,J),J=J1,J2)
40    CONTINUE
C
      RETURN
C
1100  FORMAT(/F5.1,4X,4E14.4)
1120  FORMAT(/' Total Collective Liquid dose : ',E14.4,'  man-Sv/year')
1125  FORMAT(/' Total Collective Air dose : ',E14.4,'  man-Sv/year')
1127  FORMAT(/' Total Collective (Air & Liquid dose) : ',E14.4,
     1        '  man-Sv/year')
1150  FORMAT(/' ** Coll equiv dose rate (man-Sv/year) **',2X,
     1  'Source in water : ',E12.4,' Bq/L')
1400  FORMAT(////' ** Indv Equiv dose rate (Sv/year) **',2X,
     1  'Source in water : ',E12.4,' Bq/L')
1200  FORMAT(//25X,'Sector (clockwise from N)',/2X,'Rad(km)',7X,
     1      4(I2,12X))
1250  FORMAT(//2X,'Rad(km)',4X,'Tot Rad Coll Dose')
1300  FORMAT(2X,F5.1,8X,E12.4)
1260  FORMAT(//2X,'Rad(km)',3X,'Tot Rd Col Air Dose',3x,
     1       'Tot Rd Col Liq Dose',3X,
     2       'Tot (Gas & Liq dose)')
1305  FORMAT(2X,F5.1,3(10X,E12.4))
2200  FORMAT(8X,'     Local Liquid Dose Rates for Nuclide ',A6,
     1       '** ',A24/
     1       8X,'     ----------------------------------------'//)
      END
```

Table D.7 - Sample Input Data Files for CLDOSL

```
*** File darl.loc ***
Site specific data for Darlington-
Local collective dose model
*
Darlington                ,  :: Site name - A24 (24 characters including blanks)
*
  :: # of radial points and their values in km (I2,F5.1)
 6   2.5  7.5 15.0 25.0 35.0 45.0
*
  :: # of sectors and wind rose by sector n to nw clockwise (%) (I2,F5.1)
 8 13.0 15.0 10.5 3.5  4.0 12.5 24.0 14.0
*
  :: Population figures for R1 to Rn on same line & by sector N to NW clockwise
    1000   15000   20000   10000    7000   15000              :: N (IB)
    8000   10000   10000   10000    6000   20000
    1000    5000    5000    5000   10000   10000
       0       0       0       0       0       0
       0       0       0       0       0       0
       0       0       0       0       0       0
    1000   15000   70000   40000  120000  400000
    1000   10000   30000   20000   40000   40000              :: NW
*
  :: Fraction of population taken as infants ( < 2 yrs) (F5.1)
 0.03
 :: Atm. dilution param P(01) for isotropic wind rose H=50m R=R1 to Rn (F8.1)
  1.2E-7  3.5E-8 1.45E-8 7.3E-9  4.6E-9  3.3E-9
*
  :: P(01) uniform average wind and angular sector J for source of land produce
 1.45E-8 9
*
  :: P(02) water dilution param assumes average value for entire region
  :: Note the conversion from Bq/s to Bq/l is included in the source term
  :: P(02) is the dilution after the outfall
    0.23
*
*
```

```
  *** File ptlp.loc ****
  Site specific data for Pt. Lepreau
  Local collective dose model
*
Pt.-Lepreau                    :: Site name ( 24 characters including blanks)
*
  :: # of Radial points and their values in km
 9  2.5  7.5 12.5 17.5 22.5 27.5 35.0 45.0 55.0
*
  :: # of angular sectors & Wind rose by sector N to NW clockwise (%)
 8 10.0  9.2 11.2  4.2 15.0 10.0 20.8 16.6
*
  :: Pop'n figures for R1 to Rn on same line & by sector N to NW clockwise
      91      414      252       69        0        0     1735     1178      430  ::N
     164       96      228      360        0     3173    82381    95891   122077
       0        0        0        0        0        0       90      198      596
       0        0        0        0        0        0        0        0        0
       0        0        0        0        0        0      403      270      270
       0        0        0        0        0        0     1635     1630     2549
       0       75     1258      220     1878     2392     1580     4578     1694
     169      278      115       37       81      340      186      379      386  ::N
*
  :: Fraction of population taken as infants ( < 2 yrs )
 0.03
*
  :: Atm. dilution  parameter P(01) (for isotropic wind rose   Hr=8760) R-R1 to
  1.2E-7  3.5E-8  1.8E-8  1.2E-8  8.5E-9  6.4E-9  4.6E-9  3.3E-9  2.5E-9
*
  :: P(01) (uniform wind) and ang. sector J for source of land produce
  1.9E-9 2
*
  :: P(02) water dilution parameter ( assume average value for entire region)
  :: NOTE: The conversion from Bq/s to Bq/L is already included in the source
  ::emmision rate (Bq/L) at the outfall. P(02) is the dilution after the out-
 1.00E-3
*
```